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ENERGY ANALYSIS PROGRAM

FY-1979

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ENERGY ANALYSIS PROGRAM

INTRODUCTION: THE CASE FOR ENERGY ANALYSIS

W. Siri

Is energy analysis basic research or even a discipline? As perceived by the practitioners of the established disciplines, perhaps not. As a struggling juvenile in the world of intellectual pursuits, it may appear only a somewhat capricious application to practical problems of bits and pieces from physics, chemistry, biology, economics, mathematics and a host of other fields. Energy analysis has not yet, in the short span of its life, acquired the trappings and body of sophisticated doctrine that gives identity and prestige to the mature disciplines. It has not even acquired a proper name.

In this context, however, one is reminded that physics, chemistry, biology, mathematics and economics had humble beginnings in theology and practical problems of agriculture and commerce. Their evolution is familiar and one need not dwell on the contribution of cannons to thermodynamics, or of a bed of flowers to biology, or the troubled intellectual histories of all disciplines to achieve maturity, originally also without names to identify them.

The assertion that all scientific disciplines-or at least most of them--had humble beginnings in mundane matters does not prove that energy analysis is destined for distinction as a recognized discipline with its own adult name. It says only that the path along which it stumbles to adulthood is well trod by others. It does, however, lead to another perspective; one that may seem presumptive, and for which we ask the reader's indulgence.

The established disciplines, with the possible exceptions of theology and pure mathematics, are ruled by the energetics of the system for which each discipline has established its territorial imperative. For the "hard" sciences, this would seem self evident. In essence they explain, in diverse tongues, how energy drives and structures their chosen segments of the universe, from quarks to galaxies. This would include biology, which implicitly, if not always explicitly, addresses the energetics of complex, integrated, reproducing systems; chemistry which treats the energetics of aggregates of atoms; and physics, the science of matter's elementary constituents and energy ground rules. One can, for example, argue that evolution is in essence an energy problem. Does "survival of the fittest" simply mean that a species produced by random gene mutation--itself an energy induced process--can survive only if it can acquire, transform, and use energy to sustain itself, however preposterous its form?

But what about the soft sciences? While economics, for example, speaks of goods, and rents, of transactions, and capital, and intricate movements of money and credit, is it possible these derive from more fundamental processes of energy flows and uses? Witness the close relation of GNP to energy use, granted there are differences in energy efficiency among nations. One can add many of the other social sciences. Eskimo and Tahitian cultures differ in detail, but do the significant differences simply reflect the nature of their energy inputs? Both operated on solar energy, but coconuts and high solar insolation are bound to produce a different "system" from one functioning on blubber and low insolation. And neither culture could form appreciable capital and launch a technological culture. The needed energy was inaccesible, a situation that still represses much of the world's population today. But what of the oil-rich but underdeveloped nations? Until recently, their oil stores were to them only potential energy; others used it and grew prosperous.

Thus it can be argued, just short of tongue-in-cheek, that nearly all established research disciplines may be regarded as subdivisions of energy analysis, each tailored to the system, and more often, an aspect of the system it explores. Is there a gap in the spectrum of systems from quarks to galaxies not fully covered by an established discipline? The answer is the integrated analysis of energy in human society. The system, moreover, is unique. Human society is the only system that manipulates at will the flows, conversions and uses of energy, subject, of course, to physical law. This feature is not shared by the systems analyzed by physics, chemistry, biology, and astronomy in which energy flows unmodified by intervention of cognitive brain and opposable thumb.

Energy analysis in this context attempts to understand the volitional choices of energy use and supply available to human society, and the multi faceted consequences--the good and the bad--of choosing any one of them. To be more specific, it examines the purpose and manner of energy use--efficiency and conservation are now major intellectual attractions--as well as the sources, resources, and technology options to serve the chosen uses of energy. On the consequences side, this effort becomes more complex and diffuse. It must attempt to integrate the interacting elements of environmental, economic, social, institutional, legal, political and health impacts. To complete the field's scope, all this needs to be done spacially from the local to the global level, and temporally for a span of two decades or more, the minimum time for significant technological and institutional change.

Finally, having pleaded for a place in the sun for the juvenile field of energy analysis, how has Lawrence Berkeley Laboratory nurtured its growth? The answer lies imbedded in the short reports that follow. A substantial part of the analysis program focuses on the myriad impacts of energy technologies and fuels and the regional implications of national energy policy. The means to mitigate constraints on deployment of technologies and implementation of policy that emerge from such studies particularly interest decision makers. On the supply side, individual technologies, but more importantly, integrated assemblies of fuel cycles must be devised and evaluated. As an example, a study of Hawaii's energy options to reduce dependence on imported oil holds special fascination. It is a well-defined study area with high potential for developing its rich renewable energy resources. It is an analyst's demonstration piece with the promise that the analytical structure is applicable elsewhere.

Other studies analyze and develop criteria for building and appliance efficiency, and explore potentials for energy conservation. Still others concentrate on special environmental, economic, and technical issues. And all the studies in varying degrees advance the grasp of underlying concepts and the art of analysis. In all this activity, it may be noted, University of California (Berkeley) faculty members and graduate students play important roles.

ECONOMIC IMPACTS OF TWO ENERGY PROJECTIONS

J. Sathaye, H. Ruderman, P. Chan, and H. Estrada

INTRODUCTION

Over the past few decades the U.S. has enjoyed abundant and relatively inexpensive energy supplies --in some instances even with declining fuel prices. However, future energy supplies are likely to come from inhospitable domestic or insecure foreign environments. The price of oil and gas has risen several fold during the past few years, reflecting the impact of these two factors. The increased prices will provide some incentive to further exploration and extraction of oil and gas as well as other competitive substitutes from inhospitable domestic reserves. The marginal costs of extraction, production and conversion of all these fuels will be much higher because of more complicated and exotic technologies required to supply these fuels. The capital costs and labor requirements for energy industries will therefore assume more importance as a fraction of the total investment and employment in the economy. The capital requirements would also impose a larger burden on secondary support industries supplying materials and services for the construction of energy development facilities.

MODELS AND DATA

In order to capture these economic impacts due to development of new energy supplies, two interlinked models were used (Fig. 1). The first model, a modified version of the Energy Supply Planning Model (ESPM)[1], is used to estimate the direct impacts. The ESPM takes the fuel supplies in the scenario and sets up an annual schedule of facility construction and operation needed to provide these supplies. Based on construction and operation data for each facility, the model calculates the annual requirements for 140 types of materials and manpower skills. The construction and operating data used in estimating the capital and manpower requirements relate to facilities as they would have been designed in 1974. The data are in constant 1978 dollars, with factors such as land costs and other owner's costs included along with the manpower, materials and equipment costs.

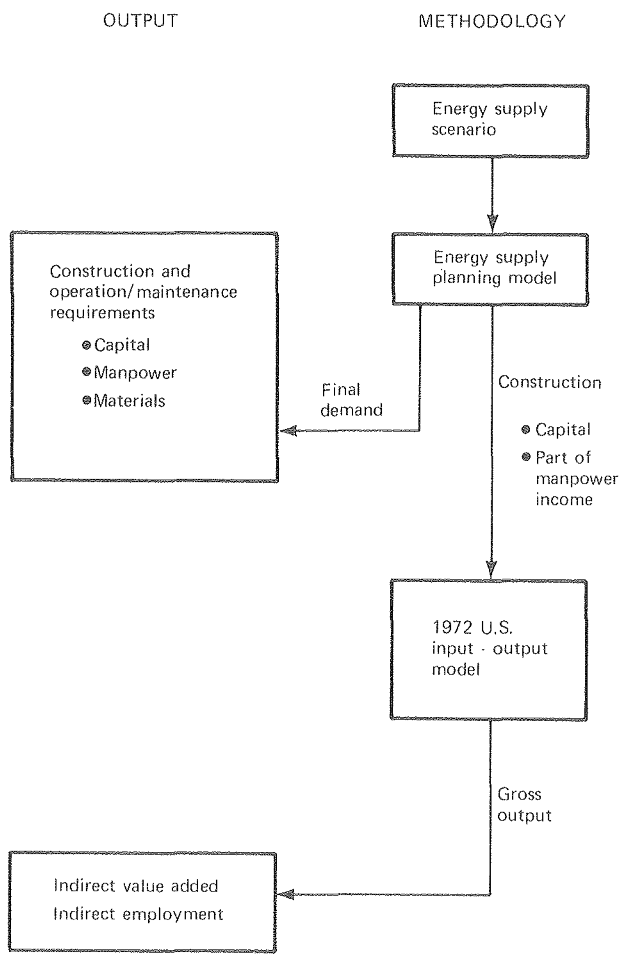

Fig. 1. Analytical methodology. (XBL 801-125)

The regional fuel demands and supplies for 1985, 1990 and 1995 are taken from the regionally disaggregated C-high and C-low scenarios. Historical fuel and electricity consumption data for 1975 provide a baseline. The locations of announced power plants in 1975, 1985 and 1990 are based on the Generating Unit Reference File provided by ORNL. Energy demand for intermediate years is estimated by interpolation. Energy demand is also extrapolated to the year 2000 to include the construction requirements for facilities coming on line after 1995.

The estimates of expenditures on direct manpower and materials for construction are the starting point for calculating the indirect impacts. The calculation is performed using a 368 sector input-output (I-O) model of the U.S. economy for 1972. The results of the ESPM calculations are disaggregated to form incremental final demand vectors for the I-O model. The model calculates the change in gross output which, in turn, is used to calculate the change in income and employment.

DIRECT IMPACTS

Annual capital investment in the energy industries increases from roughly $34 billion in 1975 to $56 billion and $52 billion in the C-high and C-low scenarios respectively. The cumulative requirements over the twenty year period from 1975 to 1995 are not very different for the two scenarios. For the C-low scenario the capital investment amounts to $899 billion, whereas for the C-high scenario it amounts to $990 billion, a difference of 10 percent. Almost 80 percent of this $91 billion dollars of additional investment is required between 1980 and 1990 with $33 billion required in the first five-year period and $40 billion in the second five-year period. The additional investment occurs due to expanded development of coal supplies, conventional and shale oil and electricity generation facilities in the C-high scenario. At the same time, the high price of oil reduces the projected oil consumption and thus decreases the refining requirements in the C-high scenario.

In addition to the capital required for new construction, the energy facilities require substantial expenditures for operation and maintenance. Excluding fuel costs, the annual O&M expenditures grow steadily from $84 billion in 1976-80 to $131 billion in 1991-95 in the C-high scenario and to $120 billion in the C-low scenario.

Manpower requirements follow the same temporal pattern exhibited by capital costs. Five year cumulative requirements are about the same for the first (1976-80) and the last (1990-95) periods for the two scenarios. In the first period they are 341 and 362 thousand man-years, while in the last period they are 428 and 442 thousand man-years for the C-low and C-high scenarios respectively (Table 1).

Requirements for the C-high scenario are 20 percent higher during the decade from 1981 to 1990. The majority of this increase is due to the increased requirements for constructing new coal facilities, with smaller increases due to increased shale oil production and electricity distribution and transmission activities.

Most of the demand for occupational skills increases at about the same rate as do total manpower requirements. However, demand for two specific skill categories, pipefitters and carpenters, almost doubles in the fifteen years from the first to the last period primarily due to construction of solar power plants and active solar heating units.

Manpower engaged in O&M of all facilities increases from 1.3 million to 1.9 and 1.8 million man-years respectively in the C-high and C-low scenarios.

INDIRECT IMPACTS

The indirect economic impacts of constructing energy facilities result from direct payments to construction labor and to the suppliers of materials and equipment. These payments are used to purchase goods and services from all sectors of the economy giving rise to additional employment and income.

The indirect or secondary impacts show generally the same trends as the direct impacts. For the C-low scenario they increase with time. Employment in industries stimulated by energy activities increases from 1.2 million to 1.35 million man-years between the first and last period (Table 1). In the C-high scenario secondary employment decreases more rapidly than does direct employment between the last two periods primarily due to decreased expenditure on equipment. Direct and indirect employment associated with C-high scenario is at its maximum in the last period. This 3.5 million man-years of employment represents 4 percent of the estimated 1978 employment (93.2 million).

There is no significant difference between the various time periods as regards the indirect employment per dollar of investment in both C-high and C-low scenarios. The ratio of indirect employment to direct employment does decrease slightly from 4.7 to 4.2 indicating a shift from capital intensive to more labor intensive energy construction activities.

The indirect employment per dollar of expenditure by labor (manpower) is higher than the expenditure on materials and equipment category. Therefore, a dollar spent on materials and equipment generates less indirect employment than a dollar spent by labor.

The estimates made of the secondary impacts are based on linear models and average values for coefficients; these impacts, however, are marginal. Since it is expected that marginal increases in employment and income are less than their average values, these results may overestimate the direct impacts. For example, construction workers in general have above average incomes and thus are likely to have a lower marginal propensity to consume. However, these employment coefficients have been corrected for increases in productivity as forecast by BLS. Overall, it is estimated that results could be 10-15 percent too high by 1990.

It should be pointed out that these indirect impacts may not represent a net increase in employment and income for the economy as a whole. If the

Table 1. Comparison of direct and indirect impacts, annual averages.

	1981-85		1986-90		1991-95	
	C-High	C-Low	C-High	C-Low	C-High	C-Low
Capital Investment (10^9 1978 $)						
Manpower	12.7	11.0	15.0	13.1	14.3	13.7
Materials	8.6	7.6	9.7	8.3	9.3	8.4
Equipment	13.8	12.0	16.0	13.9	14.9	14.4
Other	15.2	13.1	17.7	15.2	17.2	15.6
Total	50.3	43.7	58.4	50.5	55.7	52.1
Employment (10^3 man-years)						
Direct Construction	388.4	334.2	465.3	406.0	441.7	428.3
Direct Operation	1325.9	1305.0	1619.9	1517.6	1943.2	1770.8
Indirect[a]	1405.4	1211.2	1485.8	1293.3	1393.3	1346.1
Total	3119.7	2850.4	3571.0	3216.9	3778.2	3545.2
Indirect Employment per Million Dollars of Capital Investment						
Manpower	42.9	42.9	39.3	39.3	39.3	39.3
Materials, Equipment & Other	34.4	32.7	31.4	31.4	31.3	31.6
Employment per Million Dollars of Capital Investment						
Direct Construction	7.7	7.6	8.0	8.0	7.9	8.2
Indirect	36.5	33.6	33.4	33.4	33.4	33.6
Indirect/Direct	4.7	4.4	4.2	4.2	4.2	4.1

[a]Indirect employment includes the portion of direct operating required to satisfy the incremental construction requirements. The total employment therefore overestimates the actual impact by a small margin.

economy were at full employment, the energy sectors would have to compete against other industries for employees. Only if there were unemployment in the required skill categories would there be a net increase in employment. The results, therefore, should be interpreted as the amount of employment and income attributable to energy facility construction.

CONCLUSIONS

In conclusion, it should be noted that most of the larger impacts of the C-high scenario as compared to C-low scenario occur during the ten years between 1980 to 1990. These larger impacts stem from construction of more coal power plants, development of shale oil and increased electricity transmission and distribution. Demand for occupational skills, except for pipefitters and carpenters which doubles, grows at the same rate as overall capital investment requirement.

Indirect impacts amount to roughly five times the direct impacts. Again the overall impacts are small although as much as ten percent of the employment in sectors such as metal products would be devoted to producing goods for energy facility construction.

REFERENCES

1. Bechtel Corporation, The Energy Supply Planning Model, Volumes I and II, NSF-C867, San Francisco (August 1975).

ASSESSMENTS OF REGIONAL ISSUES AND IMPACTS ASSOCIATED WITH NATIONAL ENERGY SCENARIOS*

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INTRODUCTION

This study is part of a continuing effort to evaluate the regional environmental and socioeconomic impacts of future energy development. The Regional Issue Identification and Assessment program is conducted by the Regional Assessments Division, Office of Technology Impacts for the Assistant Secretary for Environment, Department of Energy. This study is an analysis of one of a number of national energy scenarios developed by DOE.

ACCOMPLISHMENTS DURING 1979

Scenario Discussion

As a basis for this study, the Series C energy scenario developed by the Energy Information Administration[1] was used for the projected energy development pattern for the nation and the region. It is a projection based upon the continuation of energy policies in effect at the beginning of 1978. The main assumptions are:

- constant world oil prices of $15.32/bbl in 1978 dollars,
- increasing reliance on oil imports through 1990,
- continued decline in domestic natural gas production (lower forty-eight states),
- slight increase in domestic oil production due to Alaskan and OCS development, and
- continued growth in the use of coal and nuclear energy.

Energy supply and use projections based on this scenario are summarized in Table 1 for both the nation and for Region 9. The regional energy mix changes little over the next 15 years, with the largest changes occurring due to increased use of coal, nuclear and geothermal energy sources. Overall, the change to 1990 represents an annual growth rate of 1.8% per year, compared with a projected 2.9% per year for the nation as a whole. For electrical energy, the regional growth rate is 2% per year, contrasted with a 4.6% annual rate for the total nation. The resulting energy use, on a per captia basis, is shown in Fig. 1.

The issues and impacts discussed in this report are for the states in Federal Region 9, consisting of California, Arizona, Nevada and Hawaii. A detailed energy facility siting pattern was formulated, based upon the forecasted energy use by fuel type, and upon the present development plans of energy supply industries in the region. Figure 2 illustrates changes in electrical generating capacity by state. Production and processing of fossil fuels is expected to take place at existing sites or installations, with the exception of an additional amount of OCS oil and gas activity off the California coast.

Regional Assessment Results

The assessment of impacts and issues arising from this national energy scenario was done for several study areas--air quality, water quality and availability, ecology, land use, solid waste, local socioeconomic, and institutional and political issues. This section summarizes the results by issue area. Air quality, water, regional economic and institutional and political issues are also discussed in individual reports elsewhere in this Annual Report.

Air Quality

Changes in air quality were estimated from long-range transport of particulates and sulfur oxides and from localized changes in emissions in each county. Based upon present and projected energy and process facilities, sulfur oxide concentrations are projected to increase by 1990 in the agricultural regions of California from emissions in the San Francisco Bay area, and in the South Coast Basin. Violations of the Prevention of Significant Deterioration (PSD) standards for sulfur oxides are possible for Class I areas in southern California due to emissions in the South Coast Air basin. Major emission sources in Nevada and Arizona, both power plants and process sources such as smelters, contribute to sulfur oxide problems in adjoining states of New Mexico and Utah.

Based upon the scenario projections of fuel use and new generating capacity requirements, emissions estimates from both stationary and mobile sources were used to predict changes in air quality for each Air Quality Control Region (AQCR). Continued violation of ambient air quality standards is expec ted for most of the urban basins in the region. In addition, siting in specific rural areas may be constrained by continued non-attainment problems for certain pollutants for which no local emissions offsets are available. Figure 3 shows the results of the local air quality calculations for each AQCR for oxides of nitrogen. Other pollutants show similar results.

Water Quality and Availability

Overall, regional water quality impacts do not appear to be significant as long as the present permitting processes and regulatory enforcement policies continue in the future. Point sources should not, therefore, constitute major sources of water pollutants; however, possible site specific concerns

Table 1. National and regional energy consumption based on the Series C scenario.

National energy consumption (10^{15} BTU per year)	1975	imports*	1985	imports*	1990	imports*
oil	32.8	.27	43.9	.38	48.5	.43
natural gas	20.0	.05	19.1	.10	19.3	.13
coal	12.8	(.14)	21.2	(.09)	25.4	(.08)
nuclear	1.8	0.0	6.2	0.0	10.3	0.0
hydro + geothermal	3.2	0.0	4.2	0.0	5.0	0.0
TOTAL	72.6		96.9		110.9	
Regional energy consumption (10^{12} BTU per year)						
oil	3665	.57	4263	.49	4554	.53
natural gas	2213	.85	1945	.79	2100	.78
coal	247	.36	397	.34	409	.34
nuclear	65	1.0	359	1.0	611	1.0
hydro + geothermal	510	0.0	773	0.0	822	0.0
TOTAL	6700		7738		8507	

Consumption by end-use sector

	National (10^{15} BTU)			Regional (10^{12} BTU)		
	1975	1985	1990	1975	1985	1990
residential	10.0	12.1	12.8	928	805	816
commercial	7.3	7.8	8.2	671	600	611
industrial	18.1	26.9	32.3	1127	1610	1901
transportation	18.6	21.4	23.3	2382	2831	3063
TOTAL	54.0	68.2	76.6	5108	5846	6391

*Fraction of fuel supplied by foreign or out-of-region imports (indicates net export fraction).

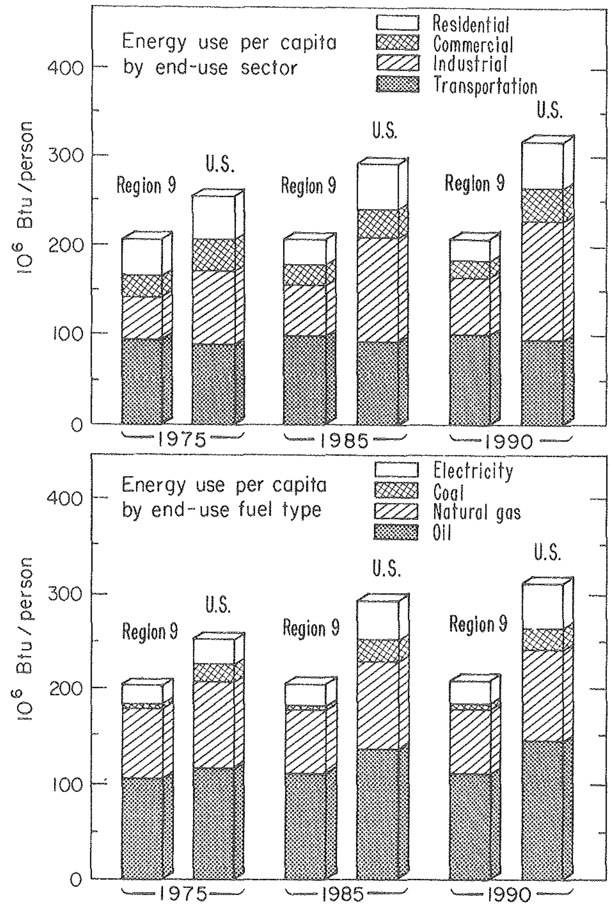

Fig. 1. A comparison of present and projected energy use per capita for Region 9 and the U.S. (XBL 797-2042)

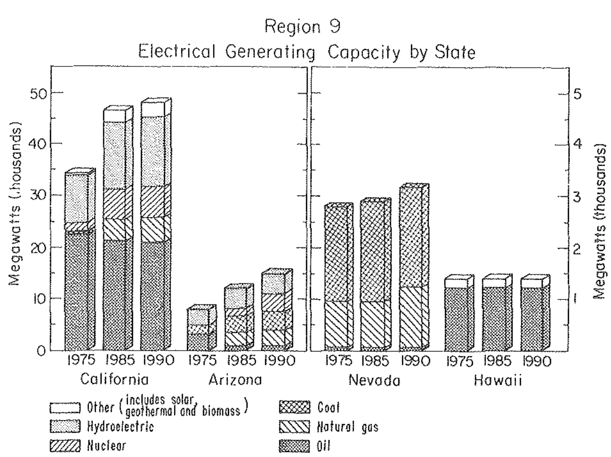

Fig. 2. Electrical generating capacity by state (Region 9). (XBL 797-2041)

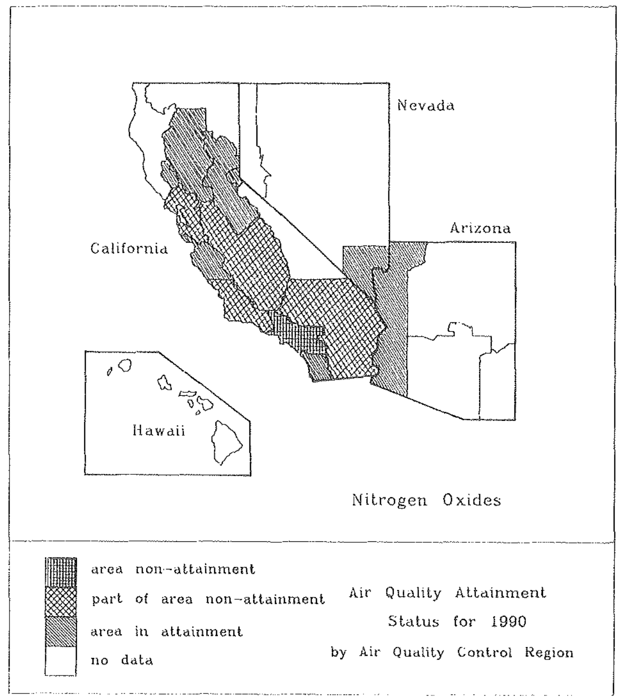

Fig. 3. Projected air quality status for 1990 by air quality control region (nitrogen oxides). (XBL 797-10564)

have been identified. Water quality impacts may result in areas with new or expanded geothermal energy development.

Water availability issues in this region focus primarily on the future uses of fresh water and the competition among many potential users. The lack of available water in certain parts of the region may constrain energy development in those areas unless sources of reusable water, such as municipal wastewater, are made available. The use of such water raises the secondary issue of the effect of cooling tower drift and blowdown on surrounding land uses.

Ecology

Although ecological impacts are generally site-specific, broader problems such as impacts upon sulfur-oxide sensitive crops will also be important if fuel burning increases as projected. Parts of California have large acreages of sulfur-oxide sensitive crops, as shown in Fig. 4, which total to nearly 2 billion dollars in value. Another important aspect of energy facility siting, especially in California, is the possible conflict with endangered species habitat. In Arizona, much of the land disturbed by strip mining has not been reclaimed, creating additional pressures upon rare and endangered species in that area.

Land Use

The major scenario-related land use issues in the region involve those projected facility sites

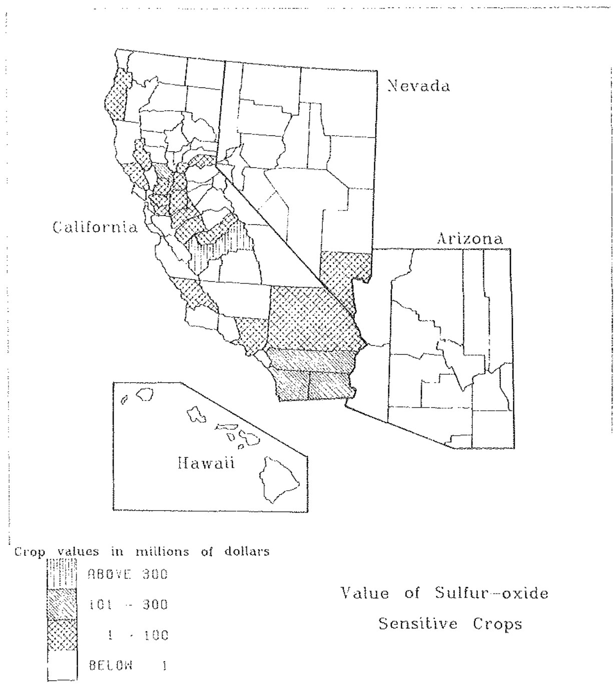

Fig. 4. Value of sulfur-oxide sensitive crops. (XBL 797-10571)

which conflict with other high-priority land uses, particularly in the coastal zone and in agricultural areas. Increases in refinery capacity, necessitated by the projected increase in the use of oil in the region, will conflict with, and in some cases be constrained by, existing coastal land use regulations and plans. Energy development in or near agricultural areas presents possible land use conflicts because of the increases in air emissions and conflicting demands for fresh water.

Solid Waste

Solid waste residuals resulting from increased energy activity in the region are not expected to be a serious regional problem, although this assessment presupposes that waste materials will be disposed of in a way that will not affect water quality.

Local Socioeconomics

At a regional level, the scenario presents no major socioeconomic issues. However, local issues will be very important, especially in those cases where the energy development is very site specific such as geothermal energy development. Local employment and population impacts appear to be small or moderate except in those rural coastal counties where new off-shore oil and gas production will induce on-shore development impacts. Other sociological factors may be important in those rural areas where increased energy development is expected. Among the most important of these are potential conflicts with Indian tribal cultures in Arizona due to increased coal mining activity, and the potential changes in community infrastructures resulting from geothermal development activities in predominately rural areas in California.

Institutional and Political

While each state in the region has a unique set of institutions, there appear to be a number of issues common to all. Public awareness and debate over environmental and energy issues in the region have resulted in the establishment of local and statewide institutions charged with resolving these problems. These institutions, along with other political factors, may constrain certain types of energy development in the region. The use of natural gas in new power plants, as proposed by the scenario, appears to be infeasible due to federal and state regulatory actions that have given a low priority for such uses. Large portions of Nevada, Arizona, and parts of California are under direct federal control, and siting of facilities or transmission lines will require federal approvals.

Finally, the economics of various energy supply sources influence both private and public institutional decision making. Some of the provisions of the scenario appear economically less viable than alternatives such as conservation and improved end-use efficiencies, and as such, may not be implemented.

PLANNED ACTIVITIES FOR 1980

A second regional assessment study has been initiated, based upon the most recent National Energy Plan (NEP-2).[2] This plan incorporates a number of new DOE energy policies, and is based upon a more up-to-date set of energy resource prices and constraints. The analysis will extend to the year 2000, and will cover a broader range of energy supply technologies than the previous study.

FOOTNOTES AND REFERENCES

*Condensed from Lawrence Berkeley Laboratory report LBL-9609.

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2. U.S. Department of Energy, "National Energy Plan II" (May 1979).

EVALUATING AIR QUALITY ASSOCIATED WITH FUTURE ENERGY PROJECTIONS

R. Sextro and M. Messenger

INTRODUCTION

Air quality considerations are a key issue in the assessment of future energy projections for both energy production and use. Given a set of assumptions regarding choices of sites and technologies, changes in air quality due to a given energy scenario can be tested against present and future air quality standards and emissions regulations as a way of examining possible constraints to energy development and use.

ACCOMPLISHMENTS DURING 1979

As part of the analysis of regional impacts associated with the national energy scenario described in this Annual Report,[1] changes in air quality were estimated both as a result of local emission sources and effects due to long-range transport of pollutants. The resulting projections of air quality were compared with state and federal air quality standards and with regulations governing Prevention of Significant Deterioration (PSD) increments. Possible degradation of visibility in Class I air areas was also assessed.

Analysis Procedure

The six national laboratories involved in the assessment project developed a common set of analytical procedures for the study. Local air quality projections were made using a roll-back technique which assumes that the ratio of future emissions and the resulting air quality remains the same as the ratio of present emissions to present air quality. The use of this technique implies a number of assumptions, among them are that meteorological conditions in the present or base year will remain the same in future years and the spatial distribution of emission sources will be approximately the same in the future as in the base year. In those areas where the emissions increments were large compared with existing sources, a separate procedure was used to estimate the contribution to local air quality from the large incremental sources. For Region 9 the detailed siting pattern based upon the scenario did not result in the siting of large emitting facilities in areas where existing sources are small.

In addition to the mesoscale effects estimated using the roll-back technique, long range transport of sulfur oxides and particulates was calculated. For the Western states, including Region 9, Pacific Northwest Laboratory (PNL) was responsible for these calculations (see Ref. 2 for model details), while Brookhaven National Laboratory (BNL) had a similar responsibility for the Eastern U.S. The resulting estimates of air concentrations for SO_2, SO_4, and particulates were compared with PSD Class I regulations. These estimates were also used as input parameters to the Los Alamos Scientific Laboratory (LASL) visibility computations. This model[3] was used to evaluate visibility impairment for Class I air areas.

Siting and Emissions Inventories

The siting of new energy consuming facilities such as industrial or utility boilers involves a number of complicated steps.[3] The first main element of the siting process is that the energy scenario, which specifies energy use by end use and by fuel type at the federal region level, is disaggregated into the state and Bureau of Economic Analysis (BEA) region level. The fuel use projections at the BEA level are then used for industrial fuel consumption patterns at the county level, based upon the 1974 geographic distribution of industrial facilities or major fuel burning installations (MFBI). No specific facilities were associated with these county-level projections of industrial fuel use; however, the existing (1974) MFBI combustor size distributions were used, along with information on State Implementation Plan (SIP) requirements for different facility sizes and fuels to derive emissions resulting from industrial fuel use.

Siting of present and proposed utility facilities was obtained from the FERC power plant site file maintained by ORNL and from individual utilities in the region. This information was used to site electrical generating facilities for future years. Additional "phantom" facilities were added in order to meet the fuel specific regional energy requirements of the scenario. The siting of these facilities was done at the county level.

Due to the importance of mobile sources of air pollution in this region, estimates were made for emissions from motor vehicles, based upon the region and sub-region disaggregation of gasoline use projections. These estimates include new car and fleet mileage standards, and the present and new mobile source emissions standards summarized in Table 1. As a consequence of the gasoline demand projections, the overall vehicle miles travelled are projected to incease dramatically. Because the emissions standards are based upon emissions per mile, the mobile source emissions are expected to increase in importance.

Emissions and air quality for the baseline year of 1975 were taken from a number of sources, including the NEDS emissions data base and the SAROAD air quality data base, both maintained by EPA. These were augmented by information from state and local air agencies. A major portion of California inventories was obtained from the California Air Resources Board.[4] The 1975 emissions inventories for selected California air basins are shown in Table 2.

Table 1. Federal and state emissions factors and standards for light duty vehicles.
(grams/mile)

	Hydrocarbons		CO		NO_x		SO_x	Particulates
Year	CA	U.S.	CA	U.S.	CA	U.S.	U.S.	U.S.
1975	0.9	1.5	9	15	2.0	3.1	0.13	0.45
1976	0.9	1.5	9	15	2.0	3.1		
1977	0.41	1.5	9	15	1.5	2.0		
1978	0.41	1.5	9	15	1.5	2.0		
1979	0.41	1.5	9	15	1.5	2.0		
1980	0.41	1.5	9	15	1.5	2.0		
1981	0.41	0.41	9	7	1.0	2.0	linear decrease	
1982	0.41	0.41	7	3.4	1.0	1.0		
1983	0.41	0.41	7	3.4	0.4	1.0		
1984	0.41	0.41	7	3.4	0.4	1.0		
1985	0.41	0.41	7	3.4	0.4	1.0	0.07	0.25
1986	0.41	0.41	7	3.4	0.4	1.0	0.07	0.25
1987	0.41	0.41	7	3.4	0.4	1.0	0.07	0.25
1988	0.41	0.41	7	3.4	0.4	1.0	0.07	0.25
1989	0.41	0.41	7	3.4	0.4	1.0	0.07	0.25
1990	0.41	0.41	7	3.4	0.4	1.0	0.07	0.25

Table 2. Summary of air emissions for 1975 by air basin.
(tons/day)

	South Coast			SF Bay			Southeast Desert			San Diego		
	TSP	SO_2	NO_x	TSP	SO_2	NO_x	TSP	SO_2	NO_x	TSP	SO_2	NO_x
Petroleum refining	3.5	47.0	38.	3.0	47.0	6.0	---	---	---	---	---	---
Power Plants	40.1	184	133	6.6	26.4	64.9	0.6	6.3	4.1	8.5	34.7	28.0
Industrial	8.4	14.1	75.4	6.1	15.3	102	1.4	0.3	29.4	0.6	1.9	2.7
Area Sources	97.8	0	15.3	20.2	0	2.8	81.2	0	6.0	90.5	0	0.7
Other	48.2	54.9	104.3	78.1	90.3	35.3	116.8	48.5	60.5	22.4	0	7.1
Total Stationary	198	300	366	114	197	211	200	55.1	100	122	36.6	38.5
Autos	58.4	21.8	418	28.5	5.1	204	2.7	0.8	20.1	8.9	3.3	63.6
Trucks (incl. diesels)	25.5	20.0	228	13.3	8.8	119	2.0	1.4	18.3	4.5	3.6	40.4
Other	26.1	46.0	171	13.8	26.6	71	4.4	5.2	32.4	6.6	10.2	32.0
Total Mobile	110	87.8	817	55.6	40.5	394	9.1	7.4	70.8	20.0	17.2	136
TOTAL	307	388	1180	169.6	219.5	605	209	62.5	171	142	53.8	174

Air Quality Results

Region 9 has 44 mandatory Class I air areas where Prevention of Significant Deterioration increments are 2 $\mu g/m^3$ for SO_2 and 5 $\mu g/m^3$ for particulate matter. Figure 1 shows counties in the region with Class I areas where fuel burning in either utility or industrial facilities is expected to increase. The long range transport calculations for 1990, shown in the lower half of Fig. 1, indicate possible violations of the SO_2 standards in the southern part of California. Visual air quality has been identified as an important value for all Class I air areas in this region. The visual range calculations by LASL, based upon the 1990 scenario conditions and resulting long-range transport of pollutants, show no change over the 1975 background conditions. However, plume blight due to light scattering could have a moderate effect on the Grand Canyon National Park because of increased coal-fired electrical capacity in nearby counties.

The results of the local air quality rollback calculations are summarized below by state. Basically, the present air quality picture in the region changes little by 1990. The major urban air basins, with the exception of Honolulu, generally continue to be non-attainment for one or more pollutants. Much of the improvement in the control of emissions from stationary sources is offset by increases in mobile source pollutant levels. The projected air quality status for 1990 is summarized in Figs. 2 and 3 for SO_2 and particulates, respectively. Nitrogen oxide results are described in Ref. 1.

Presently 60 percent of the counties in California are non-attainment for particulates, 80 percent are non-attainment for oxidants, and 40 percent are non-attainment for carbon monoxide. This analysis of the 30 major fuel burning counties indicates that implementation of the scenario will exacerbate most air quality problems. Emissions of particulates from mobile sources increase dramatically which, when coupled with the 20 to 30 percent increase in emissions from process sources, leads to an overall increase in most counties of 50 to 200 percent. This overrides the 20 to 40 percent decrease expected in utility and industrial sources. The resulting changes in air quality are summarized in Table 3.

Sulfur oxide emissions increase somewhat in the fuel burning counties, with increased utility emissions replacing industrial sources. However, none of the counties presently in attainment are expected to change to non-attainment by 1990.

Hydrocarbon emissions in most counties do not change significantly by 1990 as increased emissions from process sources compensate for decreased emissions from mobile sources. While this pollutant is an important precursor of oxidant formation, increased hydrocarbon concentrations do not translate directly into higher oxidant concentrations since other chemical species also play a role in oxidant formation. The increased emission levels of carbon monoxide and oxides of nitrogen from mobile sources are the major cause of air quality degradation. CO levels increase substantially for all counties, with an average increase of nearly 80 percent for industrial counties. Emissions of

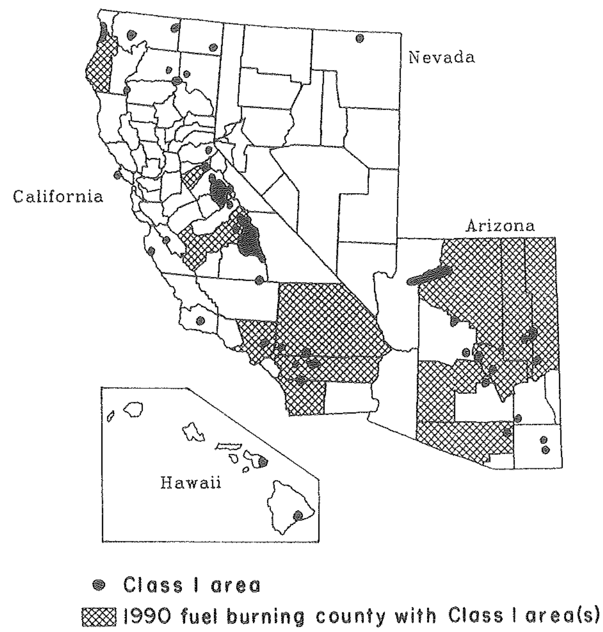

Fig. 1a. Counties in Region 9 with Class I areas. (XBL 797-10560)

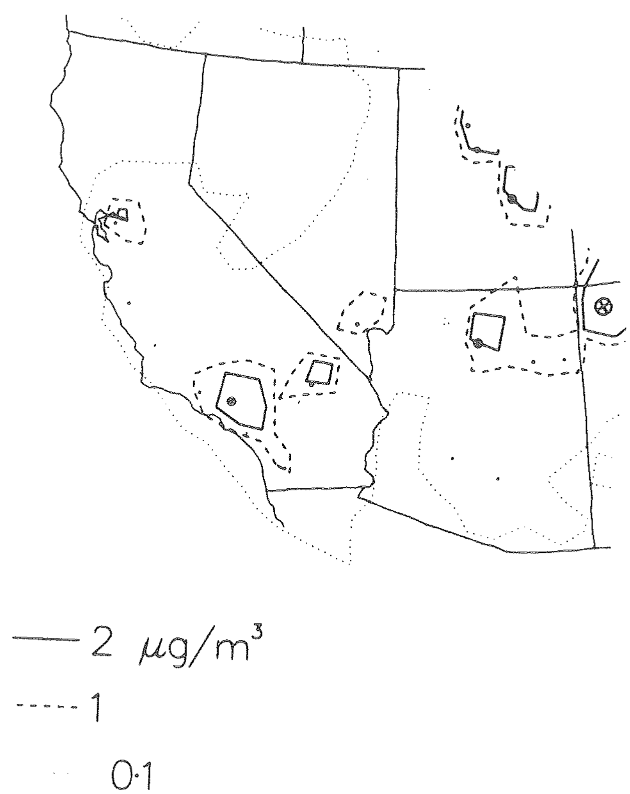

Fig. 1b. Projected SO_2 concentrations for 1990 from industrial and utility sources. (XBL 797-10486A)

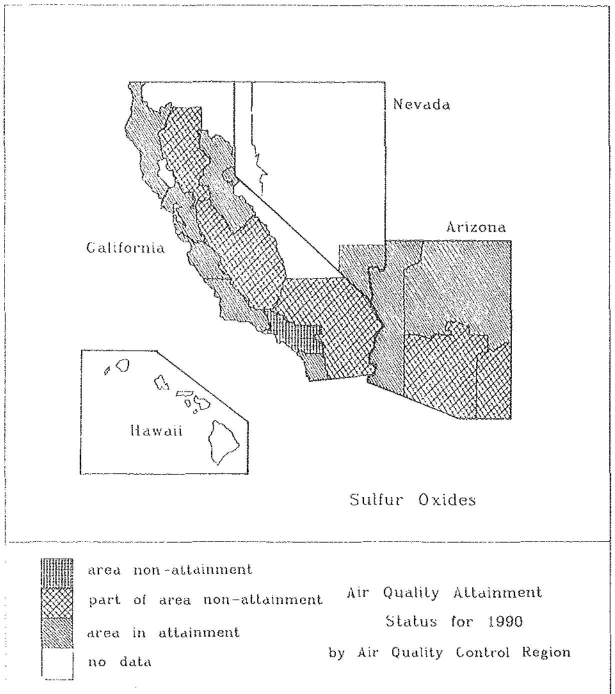

Fig. 2. Projected air quality status for 1990 by air quality control region (sulfur oxides). (XBL 797-10565)

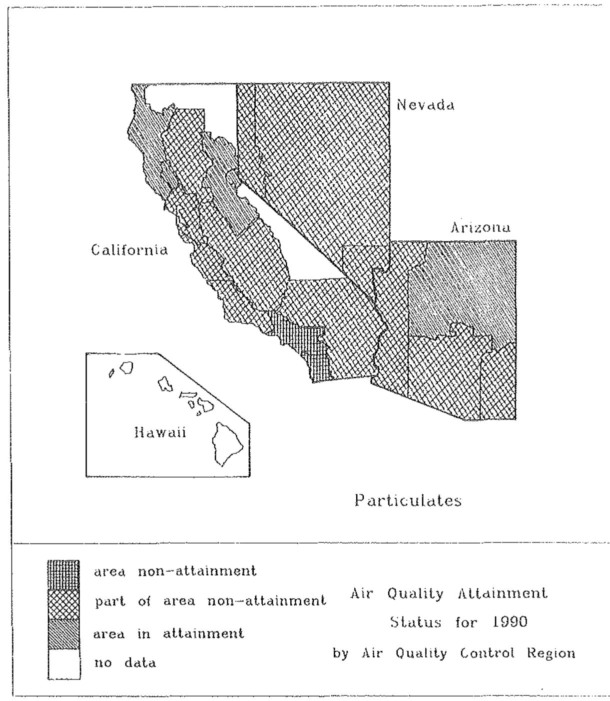

Fig. 3. Projected air quality status for 1990 by air quality control region (particulates). (XBL 797-10563)

Table 3. Changes in federal primary pollutant attainment status for California fuel burning counties from 1975 to 1990.

	Remains in Attainment		From Attainment (1975) to Violation (1990)	Continued Non-Attainment
	Static[a] or Improved Air Quality	Degraded Air Quality		
Industrial Counties (12)				
Particulates	0	0	0	12
Sulfur Oxides	2	5	0	5
Hydrocarbons	0	0	0	12
Carbon Monoxide	0	2	3	7
Nitrogen Oxides	0	4	3	5
Rural Counties (18)				
Particulates	5	5	6	2
Sulfur Oxides	7	11	0	0
Hydrocarbons[b]	1	0	0	11
Carbon Monoxide	2	7	2	7
Nitrogen Oxides	5	10	3	0

[a]Static air quality is defined as total emissions within 10 percent of 1975 baseline.
[b]No ambient oxidant data are available for six of the 18 rural counties but they are assumed to be in attainment in 1975.

nitrogen oxides from stationary sources stay close to 1975 levels.

The two major urban areas of Nevada are presently non-attainment for particulates, hydrocarbons and carbon monoxide, primarily from mobile source emissions. The high rate of gasoline consumption projected by the scenario will aggravate these problems unless proposed emission standards for motor vehicles are enforced. Particulate emissions from process sources also contribute 50 to 70 percent of total emissions in four of the six fuel buring counties in Nevada. Sulfur dioxide emissions are not a major problem in Nevada at present, with the closing of the copper smelter in White Pine county. New sources will require better emission controls, and hence will not add substantially to SO_2 air quality problems.

At present, the metropolitan areas of Arizona are non-attainment for SO_2 and particulates, and based upon the scenario, no significant change is expected. The most serious problems are due to SO_x emissions from copper smelters, and the clean-up of these emissions by 1990 is uncertain due to postponement of retrofit of control equipment.

All of the islands of Hawaii are air quality attainment areas, and the scenario projections are not expected to alter this status. The increased gasoline consumption projection raises the possibility of local violations of the CO standards in downtown Honolulu.

PLANNED ACTIVITIES FOR 1980

A new set of air quality projections will be initiated based on the analysis of a new energy scenario. A more detailed analysis of emissions offset policies currently in place at local and state levels will be conducted. In addition, modeling for large point sources will be done for facilities projected on sites where existing emissions are small.

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INSTITUTIONAL AND POLITICAL ISSUES IN POWER SITING IN THE STATE OF CALIFORNIA*

Y. Ladson

INTRODUCTION

This study was conducted as part of the Regional Issues and Identification Assessment (RIIA) Program. RIIA, developed to identify and assess the environmental, social, economic and institutional impacts of alternative scenarios defined at the regional level, is described in more detail in the second article of this Annual Report.

The analysis of institutional impacts peformed for RIIA focused on major legislative, organizational, and political factors which could either inhibit or enhance energy development in each state within DOE Federal Region 9 (California, Nevada, Arizona, and Hawaii). The primary objectives of the task are threefold:

- to identify current legislation, statutes, and organizations affecting energy development;
- to ascertain major institutional factors constraining or promoting each type of energy development; and
- to assess the impacts of conflicts, barriers and promotional factors which arise from the national energy scenario.

A case study approach was selected as the vehicle to identify the relevant issues. The case studies chosen in each state allowed the analysis to focus on the actions associated with a single facility or decision. These studies should illuminate the major issues which will arise for most facilities.

ACCOMPLISHMENTS DURING 1979

In California, the controversial Sundesert nuclear power plant proposal and the siting of an LNG terminal were selected as possible case studies for FY 1979 because they had drawn much attention state-wide and involved a wide range of agencies and interest groups. In the end, Sundesert was chosen as the issue for the first case study.

The Case Study

The objective of the case study is twofold: 1) identification of major institutional structures, organizations and actors affecting energy development; and 2) illustration of institutional conflicts, constraining factors and the political nature of issues which arise in the decision-making process. The DOE energy development scenario was used as a basis for an assessment of issues arising from the Sundesert case study effort.

Any assessment of institutional impacts of power plant siting in California must start with a review of the legislative authority creating the state's siting permitting process and energy development program. Thus the first task was to examine the California Energy Resource Conservation and Development Act of 1974, the most comprehensive state energy legislation in the nation. The next phase of the study consisted of a review of the literature and publications concerning the Sundesert nuclear power plant proposal and related power plant siting and energy development program in the state of California. An examination of the major state "energy agencies" included agencies identified in the Regional Energy Data Book as having a major role in energy facility siting. A detailed critical review of the State's Energy Resources Conservation and Development Commission was conducted because of its role as the central, one-stop energy facility siting agency with exclusive state level authority to approve and certify power plants.

A review of public hearing records identified major actors who participated either as proponents or opponents to the siting of the nuclear power plant. These organizations were contacted for further information or for clarification of issues which developed during this controversy.

The final phase related identified issues which arose during the case study to the RIIA scenario. Issues which were identified included both scenario-specific and non-scenario-specific.

The Issues

The analytical process described above identified several key institutional issues. In summary these include:

- Nuclear Development

  The State's nuclear safety legislation prohibits any new nuclear facilities until an adequate federal nuclear waste program is developed. Further, since the Three Mile Island accident, concerns raised by state government officials and environmental groups have jeopardized the licensing and operation of plants presently under construction.

- Jurisdictional Disputes

  Jurisdictional conflicts between the State Energy Act and other state and federal laws constrain the power plant siting process resulting in permit delays.

- Air Pollution Tradeoffs

  Air pollution tradeoff policies must be addressed on a case-by-case basis. Inter-pollutant or inter-basin tradeoff questions must be resolved; this issue affects both utility and industrial siting decisions. Major fuel burning installations will require emission offsets in non-attainment areas.

- Alternative Technologies and Renewable Energy Sources

  Geothermal, solar, coal gasification, wind, cogeneration and biomass are all seen as alternative energy sources. State government supports a diversified energy mix and is strongly pursuing the development of many of these options.

PLANNED ACTIVITIES FOR 1980

The institutional and political issues in power plant siting in California can be categorized into three areas: legislative and regulatory decision framework; intra-interagency jurisdictional questions; and local political traditions. Each of these areas will be studied in detail under RIIA II through the development of additional case studies.

FOOTNOTES

*Condensed from Lawrence Berkeley Laboratory report, LBID-052.

INTEGRATED ASSESSMENT FOR ENERGY-RELATED ENVIRONMENTAL STANDARDS

*J. Holdren**

INTRODUCTION

The aim of this two and a half year project is to explore--and to suggest improvements in--the assessment mechanisms available for use in the formulation of environmental standards applied to energy technologies. At the core of the work is the idea that rational standards should be based on integrated assessment. That is, the assessment should compare the environmental benefits sought by regulatory action not only to the direct economic costs and the transaction costs of the regulation but also to the regulations's consequences in displacing environmental effects from one energy source to another, one fuel-cycle step to another, one pollutant to another, one environmental medium to another, one class of victims to another, and so on.

Background

Environmental impacts of energy technologies arise from many stages in the flow of an energy source from discovery to end-use (e.g., mining, processing, combustion), propagate via disruptions in many media (e.g., air, water, soil), and manifest themselves as many different undesirable effects (e.g., occupational disease, public disease, property damage, loss of service functions performed by ecosystems).[1] Attempts to control environmental impacts have evolved in a piecemeal fashion, focusing typically on one stage at a time, one medium at a time, one effect at a time. But the pieces are not independent, and the damages associated with each cannot be independently minimized. As the degree of control sought in different sectors has increased, the nature of the troublesome linkages has become clearer. Controlling air quality may impose additional burdens on water and soil; emissions restructions at the combustion stage may push impacts back to the processing stage (as, e.g., in solvent refining or liquefaction of coal); and reductions in public disease may be bought at the expense of occupational health. The substantial inability to systematically and objectively determine whether any given "trade-off" of the kind just described leaves us better or worse off in the aggregate--that is, the lack of an integrated environmental assessment capability--is emerging as the central problem of contemporary environmental policy.[2]

History of this Study

Following preliminary discussions with the projects's sponsors in the Office of Technology Impacts of the U.S. Department of Energy, work on this study began in June 1978. The effort consisted, in its inital phase, of the following two elements:

(1) literature review and synthesis exploring the adequacy, for purposes of integrated assessment, of the tools and data presently available in environmental science and environmental economics;

(2) case studies illuminating the extent to which available tools and data were actually used in the decision-making processes that led to major U.S. federal environmental standards relevant to energy technologies.

This work was carried out by the three senior investigators on the project: John P. Holdren, Principal Investigator and Professor of Energy and Resources, Anthony C. Fisher, Professor of Energy and Resources and of Economics, and John Harte, Senior Staff Scientist and Head of the Ecology Group, Energy and Environment Division, and four Graduate Student Research Assistants (Charles Blanchard, Veronica Kun, Michael Simpson, and Kathy Tonnessen). The results were described in six papers: two critial reviews surveyed economic valuation of environmental damages and status of major environmental data bases and integrated environmental economic models; and four case studies covered the Federal Water Pollution Control Act, the EPA's New Source Performance Standards for Fossil-Fuel Power Plants, the national emissions standards for mobile sources of air pollution, and the Surface Mining Control and Reclamation Act of 1977.[3-8]

The initial survey papers and case studies served to identify and characterize the obstacles that stand in the way of more systematic assessment of the benefits and costs of alternative environmental policies. With respect to the tools available in environmental science and environmental economics, these obstacles include problems of:

1. comprehensiveness/completeness (some links between contemplated actions and well-being do not get identified, and for some that are identified the information needed to characterize the link is missing);

2. quantification/accuracy (many effects that can be identified and characterized cannot be quantified, and much of what has been quantified is inaccurate or characterized by very large uncertainties);

3. comparability/valuation (even among effects that have been accurately quantified, the units of measurement are often incommensurable, which frustrates comparative valuation, and even where valuation is possible the capacity to weigh alternate distributions of costs and benefits among winners and losers is absent).

With respect to the application of available tools in actual standard-setting decisions, important additional obstacles revealed by the case studies (which employed interviews with parties to the decisions as well as use of documentary materials) include:

1. lack of awareness, on the part of decision makers and their staffs, of the full range of analytical tools that exist;

2. lack of confidence in available tools and data;

3. lack of time or money to apply tools and data to pending decisions;

4. agency structures and division of responsibilities that discourage or frustrate integration across media, fuel-cycle steps, energy sources, and so on;

5. the influence of political pressures on environmental decision makers.

(It must be noted that the last item is not necessarily an obstacle to systematic assessment, but can be a legitimate component of it.)

ACCOMPLISHMENTS DURING 1979

Workshop

The initial activity in FY 1979 was the "Workshop on Integrated Assessment for Energy-Related Environmental Standards", held at LBL November 2 and 3, 1978. A major purpose of the workshop was to expose the results of the FY 1978 effort--published in the papers described above--to the scrutiny of an array of individuals who either have studied these questions from other perspectives or who have been participants in the kinds of standard-setting processes under study. Accordingly, invited discussants included people with experience in the Congress and Executive Branch agencies with environmental responsibilities, as well as people from other national laboratories, universities, and industry. Following presentation and criticism of the six LBL papers, roundtable discussions explored possible characteristics of improved mechanisms for integrated environmental assessment, obstacles to implementing such mechanisms, and possible directions for the continuation of the LBL project. Proceedings of this workshop have been in preparation during FY 1979 and will be published in 1980.[9]

Approach for Continuing Work

The continuation of our investigation subsequent to the workshop has been aimed at clarifying the possibilities and pitfalls in integrated assessment relevant to standard setting for emerging energy options. One part of this work has involved the application of the analytical framework and insights derived in the earlier phase of the study to case studies of three such emerging options: photovoltaics, biofuels, and increased end-use efficiency in residential and commercial buildings. (The Graduate Student Reserach Assistants engaged in these case studies are Kent Anderson, Irving Mintzer, and Gregory Morris.) The case studies are investigating the technological characteristics of the relevant "fuel cycles" in sufficient detail to be able to identify and characterize the types of environmental effects likely to be most important. How the integrated-assessment issues identified earlier apply in the context of these environmental effects can then be explored. In parallel with--and drawing on--the case studies, a set of issue papers is treating cross-cutting, integrated-assessment issues identified in the previous phase as being both important and difficult. These cross-cutting issues are:

1. degree to which environmental damages can be estimated using data generated by markets or simulated by market-like processes;

2. accounting for effects of stochasticity (of environmental insults and of the environmental systems and processes on which they are imposed) in assessment for standard setting;

3. distributional and equity effects of standards and of uncontrolled impacts, among different groups and over time.

Additional Graduate Student Research Assistants involved with issue (1) are Suzanne Scotchmer and Nobi Yagi.

Findings of 1979 Research

The findings of the 1979 continuation outlined above are treated in a set of seven papers submitted in draft form to the Office of Technology Impacts in October 1979.[10-16] These findings include the following.

1. There are many types of biomass resources, many technologies for transforming these resources into useful energy forms, and a very wide variety of environmental effects that may result. Potentially the most serious of these are damages to ecosystem function associated with biomass project land use, water use, fertilizer use, pesticide use, and other management practices. Alteration of pre-existing processes of soil building and conditioning, and erosion control, are particularly worrisome in some approaches. On the other hand, in cases where collected biomass materials otherwise would have posed a disposal problem, the use of such materials as an energy source provides an enviromental benefit.

2. The most troublesome environmental problems potentially associated with large-scale use of photovoltaic cells are probably the health consequences of worker and public exposure to toxic substances mobilized in the production of the cells (silica dust in the case of silicon cells, cadmium in the case of cadmium sulfide cells, and arsenic in the case of gallium arsenide cells). Release of toxic cell constituents from rooftop collectors in the event of fire may be a significant pathway. Damage to desert ecosystems could be an important consequence of centralized deployment of photovoltaic technology.

3. Energy conservation is equivalent at the margin to new energy supply and should be treated as an energy source for purposes of comparison of environmental consequences per unit of energy "delivered". Use of

simply models to predict the energy yield of conservation measures in residential and commercial buildings, combined with preliminary assessment of the environmental effects of these measures, suggests a more favorable ratio of environmental cost to economic benefit than other forms of energy supply, in most cases. The most important environmental problem in residential and commercial energy conservation is probably the effect of reduced infiltration or ventilation on concentrations of indoor air pollutants, both natural (radon) and antropogenic (carbon monoxide, nirogen oxides, tobacco smoke).

4. Developing quantitative measures of pollution-induced damage to economic goods and services (e.g., damages to crops and buildings) is worthwhile but laden with theoretical and empirical pitfalls. There is reason to believe that the net effect of these difficulties in most studies done to date is to understate damages.

5. Study of pre-existing equilibrium relations between property values and environmental amenity cannot by itself predict new equilibrium property values following a change in environmental conditions, but it can yield accurate estimates of the economic benefit of small environmental improvements and a reasonable approximation of the benefit of large improvements. This approach errs on the side of overstatement of given damages (measured by the benefits of removing them).

6. Attitude surveys and related schemes to determine the economic value of environmental damages tend to suffer from a variety of types of strategic behavior (i.e., consciously self-serving responses) by respondents.

7. The cost of occupational hazards in energy production can be disaggregated into the cost of lost human capital and the cost of pain and suffering. The former cost in principle can be internalized through employer-paid insurance systems, but in actuality present Workmens' Compensation does not capture this cost entirely. Cost of pain and suffering can be internalized through wage differentials, wherein a premium is paid for riskier work. This mechanism is compromised by restricted mobility in labor markets, weak worker bargaining power, and worker misperception of risks.

8. Stochasticity in the natural environment makes it difficult to predict stresses from insults, to predict effects from stresses, and to predict human consequences from effects. The rationality of standard setting could be appreciably improved by explicit incorporation into the assessment process of the effects of stochasticity.

9. Both economic efficiency and distributional equity require that the full costs of energy use be borne by those who use the energy and choose the technologies with which it is provided. Achieving this desideratum requires that resistant externalities (those resisting internalization either because they are not monetizable or because there is no mechanism for gainers to compensate losers) either be small or be distributed naturally among users roughly in proportion to use. A number of decentralized renewable energy sources meet these conditions much better than do such conventional alternatives as coal, nuclear fission, and imported oil.

PLANNED ACTIVITIES DURING 1980

The work in FY 1980 will refine the case studies and issue papers developed in FY 1979, adding comparisons and contrasts among the case studies and exploring linkages between the issue papers and the case studies. At the same time, a synthesis will be undertaken to draw from the entire body of work in the project a set of guidelines, criteria, and suggestions for improvement of integrated assessment applied to energy-related standards. The last half of FY 1980 will be devoted largely to the preparation of a book-length final report describing the findings of the entire project.

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ENERGY WATER ISSUES

M. El-Gasseir

INTRODUCTION

This research is part of the Regional Issues Identification and Assessment (RIIA) project.[1] Specifically, we seek to identify and assess the water availability and quality issues resulting from the constraints and impacts of implementing certain energy plans, represented by a set of six Department of Energy (DOE) scenarios. Until the recent addition of Arizona, LBL's responsibility had been limited to a region including the states of California, Hawaii, and Nevada.

There are two long-term objectives to this research. The first is to identify and evaluate the water-related issues and impacts of each energy scenario. The second objective is to establish and update a water/energy information base, so that the RIIA process is improved as it progresses from one scenario to another. The lack of an adequate centralized information base and the very complex nature of the "energy/water interface" have necessitated the adoption of the second objective. The same two factors have also forced a selective approach in the analysis of the energy-water issues.

ACCOMPLISHMENTS DURING 1979

In 1979 the energy/water research activities involved two areas. In the first, an analysis of one scenario was carried out. The second area involved the preparation of a data base and an analytic framework for a more comprehensive assessment to be carried out in conjunction with a second scenario.

The First-Scenario Assessment

In the Southwest, an overriding concern is the maintenance of a delicate balance between the supply and demand for water. In the assessment of the first scenario (the DOE/EIA mid-mid scenario) a decision was made to concentrate efforts on the energy issues pertaining to water availability. Since electricity generating steam power plants are the major energy sector consumers of water, the study was further limited to this type of facility.

The methodology consisted of four steps. First, the new power plants were identified whose cooling-water requirements could not be specifically identified. This identification was accomplished by comparing the scenario with state and utility plans. The results are shown in Table 1. The scenario did not assign any new generating facilities in the State of Hawaii. Hence no futher analysis for Hawaii was carried out. In the second step, the cooling water requirements for each power plant type were established (see Table 2). In establishing these requirements allowance was made for technical

Table 1. Steam electric-generation capacities requiring new cooling-water sources, MWe

County	Combined Cycle 1985	Combined Cycle 1990	Gas 1985	Gas 1990	Geothermal 1985	Geothermal 1990	Solar 1985	Solar 1990
California:*								
Contra Costa	0	0	0	320	0	0	0	90
Humboldt	0	0	0	52	0	0	0	0
Imperial	0	0	0	46	736	876	0	0
Lake	0	0	0	0	681	731	0	0
Los Angeles	81	81	0	285	0	0	0	0
San Bernardino	0	0	0	0	0	0	20	120
San Francisco	190	190	0	0	0	0	0	0
Sonoma	0	0	0	0	381	591	0	0
Nevada:**								
Clark	0	0	0	90	0	0	0	0
Lyon	0	0	0	105	0	0	0	0
Storey	0	0	0	110	0	0	0	0

*The results for California were obtained by subtracting from the 1985 and 1990 capacities of Table 1, the 1975 capacities of the same table and the capacities of power plants recently completed or under construction. The latter data were obtained from Refs. 2-8.

**The Nevada results were obtained in a similar manner to California. However, an update on recent electric-power capacity expansion activities were obtained through personal communciations with Nevada Power Company officials.[9]

uncertainties (e.g., the method of cooling to be implemented). The third step involved the computation of each county's total future cooling-water requirements associated with the mid-mid scenario (Table 3). In the final step, the cooling requirements were compared with estimates of present and future water needs for each county's municipal and industrial, and agricultural sectors, and total use.

There are two major findings to this study:

1. For most of the Southwest Region, the proper identification and analysis of the water availability issues and impacts cannot be accomplished by comparing the new water requirements with the supply of water naturally available. Three factors prevent completion of this analysis. First, exising demand already exceeds supply with the excess being met by groundwater overdrafts. Thus new fresh water cooling needs will most probably be satisfied by diverting water from other users. Secondly, state policies exist which discourage the use of fresh water for cooling purposes.[14] A number of utilities have already started using reclaimed waste water as a coolant.[15] The competition over water and the economics of electric power generation will soon force a gradual phase out of freshwater use in evaporative cooling systems. Finally, in the Southwest there is a high degree of water regulation and (physical) integration. Lowflow analyses would be useful over very large areas comprising one or more basins or an entire state and would have to cover the entire economies of these areas. The scenarios (particularly the low-growth mid-mid scenario) are not likely to affect the outcome of such lowflow analyses to a significant extent. For a localized assessment (i.e., at the county level) the best approach is to measure the new water requirements against present and projected water use rates.

2. In spite of being a low-growth scenario for electrical generation, problems of water availability are expected. This is especially true in California's Contra Costa and Imperial counties and Nevada's Clark, Lyon, and Storey counties. In these cases, the new requirements were found to be relatively large when compared with estimates of present and projected water use rates. It is unlikely that the additional cooling requirements will be met by diverting fresh water from other users. The problems of water availability can be ameliorated by considering the use of reclaimed waste water. Adequately treated municipal waste water could meet the requirements in Contra Costa and Clark counties; however, the public health implications of cooling-tower drift could be a source of further obstacles. In the remaining counties part or all of the cooling water needs can be satisfied through the use of reclaimed agricultural drainage water. Cost and

Table 2. Cooling-water requirements of steam electric-generating facilities, 10-3 MGD/1MW$_e$ [a,b]

Facility Type	Thermal Efficiency[c] (%)	Circulation[d]	Evaporation[e]	Blowdown[f]	Drift[g]	Makeup[h]	Consumption[i]
Combined Cycle	40.3	620	7.4	4.7	0.31	12	7.7-12
Gas	38	830	9.9	6.2	0.41	16	10-16
Geothermal:							
Geysers	15.5	1,400	46	9.1	0.70	47	0-47
Imperial	16.5-9.8	2,100/3,000	60/82	27/4.0	1.1/1.5	88/84	88/84
Solar:							
Central Tower	38.5/41	440/610	5.8/8.0	3.6/5.3	0.22/0.31	9.6/14	6.0-9.6/8.3-14
Solid Wastes	25/18	2,000/3,000	24/37	15/23	0.98/1.5	40/61	25-40/38-61

[a]The values given are for peak or full capacity conditions. To obtain annual averages apply a capacity factor of 70%.

[b]In all cases, the cooling system is assumed to be evaporative mechanical-draft towers.

[c]The efficiency values for the combined cycle, gas, and Geysers cases were borrowed from Ref. 10. The efficiencies for the Imperial, central-tower, and solid-wastes facilities were obtained from Refs. 11-13 respectively. In the Imperial case the lower and the upper values represent a binary-cycle system and a steam turbine design, respectively. The solar central-tower efficiencies represent a design similar to the planned facility at Barstow, California and a Martin Marietta design where the plant can operate 24 hours on certain days.

[d]Except for the Imperial facilities, all cases assume a 15°F condenser temperature rise. The Imperial designs assume condenser temperature rise of 23 and 29°F.[11]

[e]The evaporation rates for the combined cycle, gas, and Geysers plants are borrowed from Ref. 10. The Imperial values are from Ref. 11. The evaporation rates for the solar plants were calculated under the assumption that 90 and 85% of the heat discharged by the central-tower and solid-wastes facilities would be disposed of by evaporating water.

[f]With the exception of the Imperial plants, these rates were calculated on the basis that blowdown from the towers would contain 2.5 times the amount of total dissolved solids in the makeup water. The Imperial values are from Ref. 11.

[g]In all cases, drift rates are assumed to be 0.05% of the circulation rates.

[h]Except for the Geysers and Imperial steam facilities, the makeup is equal to the sum of the rates of evaporation, blowdown, and drift. In the Geysers and Imperial-steam designs the makeup is equal to the sum of the rates of evaporation and drift. The makeup rates represent the withdrawal rates.

[i]In all cases other than the geothermal types, the lower rates of consumption assume that the blowdowns are adequately treated before being returned to the original sources of water; these values are the sum of evaporation and drift losses. In the Geysers case, consumption is allowed to approach the zero value since the geothermal steam condensate is the cooling medium and since the reinjection of water at rates equal to the rates at which geothermal steam is withdrawn may not be considered necessary (to prevent land subsidence).

technical uncertainties cast some doubt over the effectiveness of this alternative in the near future.

Preparing for RIIA II

Efforts have been made to establish a data base and a methodology for making an integral assessment of the water availability and water quality implications for upcoming DOE scenarios. Because of the progress already made in the area of water availability the emphasis has been on water quality. The work accomplished covers both point and nonpoint sources of pollution. In the case of the point source pollution, data on steam electric power plant and petroleum refinery effluents have been obtained from the various regional water quality control boards and from the U.S. Environmental Protection Agency. These data will permit an estimation of the pollutant loading rates of both existing facilities and of future installations.

While efforts to control the pollution from point sources have been successful, the nonpoint sources remain largely unchecked,[16] and will soon be the major contributors of certain pollutants. Energy development could have profound effects on the course of this type of pollutant and on the efforts to control it. A search is now being conducted to find ways for quantitatively linking certain types of nonpoint pollution with hypothesized energy activities such as those prescribed in a RIIA scenario. Because of the quality of available data and the importance of the problem itself, the contribution of transportation fuel-end use to urban runoff pollution has been selected for the initial efforts.

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Table 3. Cooling water requirements

State and County	Drift,* 1000G/D		Consumption,** MGD	
	1985	1990	1985	1990
California				
Contra Costa:				
Gas	0	130	0	3.3-5.3
Solar Solid Waste	0	88-140	0	2.3-5.5
Total	0	220-270	0	5.6-11
Humboldt:				
Gas	0	22	0	0.53-0.86
Imperial:				
Geothermal	790-1,100	940-1,300	62-65	73-77
Gas	0	19	0	0.47-0.76
Total	790-1,100	960-1,300	62-65	74-78
Lake:				
Geothermal	480	510	0-32	0-34
Los Angeles:				
Combined Cycle	25	25	0.63-1.0	0.63-1.0
Gas	0	120	0	2.9-4.7
Total	25	140	0.63-1.0	3.5-5.7
San Bernardino:				
Solar	4.4-6.1	26-37	0.12-0.27	0.72-1.6
San Francisco:				
Combined Cycle	59	59	1.5-2.4	1.5-2.4
Sonoma:				
Geothermal	270	420	0-18	0-28
Nevada				
Clark:				
Gas	0	37	0	0.92-1.5
Lyon:				
Gas	0	43	0	1.1-1.7
Storey:				
Gas	0	45	0	1.1-1.8

*The concentration of total dissolved solids in the drift from the geothermal power plants is assumed to be 3 and 21 times that of the intake cooling water (Ref. 11). For the rest the concentration factor is 2.5. G/D is gallons per day.

**The upper values represent the withdrawal rates. MGD is million gallons per day.

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THE DEVELOPMENT OF NUMERICAL METHODS FOR CHARACTERIZATION OF AQUATIC SYSTEMS DISSOLVED OXYGEN PROFILES

M. Henriquez

INTRODUCTION

The recent passage of Public Law 92-500 has mandated strict water quality standards for much of the nation. As a result there has been increasing interest on the part of the water management community in methods which can simulate the impact that man made or natural actions will exert on aquatic systems. In the past, techniques for forecasting water quality phenomona have been based on predictive or deterministic methods. As a result of renewed interest in the field, there has been a realization that these methods, while adequate in the past, often fail to reflect complex synergistic relationships which increasingly characterize the nation's waterways. Simply put, the problem has often been the result of fitting linear models to essentially non-linear natural systems.

Many new approaches have been developed which take these factors into account. Often this new school of numerical analysis is characterized by a high degree of specificity in terms of the aquatic system to which the approach is applied. For example, recent efforts include one by Chandler[1] who developed a biological approach to water quality modeling by using a modified form of the standard diversity index calculation. Salis and Thomann[2] presented a simplified approximation of a three dimensional time variable system. This was based on reaction kinetics as described by non-linear theory. An important qualification of this approach is that it assumes steady state conditions in which a single nutrient is limiting. Hochman et al.[3] have developed a stochastic pollution model which was applied to dairy waste runoff into San Francisco Bay. It soon became clear that the wide range of approaches and their concurrent underlying assumptions more often than not tended to limit the application of a given algorith to a wide range of potential real world impacts. General methods, on the other hand, are useful for 'first cut' approximations but at the expense of reliability and precision.

ACCOMPLISHMENTS DURING 1979

Clearly there is a need for numerical methods to possess sufficient incremental detail for application to a range of questions, while at the same time to provide reliable output in a form which allows intelligent decision making by those who may not be familiar with the intricacies of specific calculations. Such a model has been developed by the author during 1979. The purpose was to develop a quantitative methodology to assess the impacts of existing and proposed energy generating activity on adjacent water quality. It is based on the accepted role of dissolved oxygen (DO), and the biochemical oxygen demand (BOD) as basic quality indicators for natural systems. The algorithm is heuristic and reiterative. The results may be displayed as a two dimensional representation of a 3 variable interaction. This display option provides a useful and realistic picture of the interaction under study. At the same time it is compatible with newly developed techniques for energy analysis through matrix theory and interactive computer cartography.

The model assumes that in the base case natural system changes in dissolved oxygen are largely the result of photosynthetic oxygenation which is directly proportional to algal cell concentration within the reach. The model is reiterative and utilizes the following procedure:

1. Calculation of maximum oxygen evolution rate in mg/l/hr,
2. Determine respiration coefficiencies,
3. Determine rearation constants by means of the O'Connor-Dobbins formulation,
4. Use the results of steps 1 to 3 to determine net photosynthetic oxygenation, deoxygenation and the appropriate reaeration rates.

The results of step 4 are modified by inclusion of log based velocity terms which reflect specific reach flow characteristics. From this, one is able to determine an accurate expression for two dimensional dissolved oxygen levels. A rearrangement of terms provides an expression for the calculated maximum allowable BOD for which a given reach can self correct.

Having obtained this "first cut" result for oxygen parameters, it is desirable to elucidate the manner in which these levels change with respect to changes in the steady state. The second increment of the model involves solving a series of six sequential non-linear equations which provide an expression of DO levels in two hour steps. The terms of these equations may be altered to reflect conservative or non-conservative reach loadings. These might include thermal loading or chemical addiitives such as chlorine or alum. Using the values from the preceding steps in a modified version of the Streeter-Pheleps equation, an expression for reach specific aquatic productivity is obtained which reconciles the often observed difference between 5 day BOD levels and real world water quality for a particular reach.

Having completed these steps, the model provides an expression which relates the cost of treatment with respect to plant size and degree of pollutant removal. This expression is based in part on reach specific information provided as model outputs and on engineering data characteristic of the proposed treatment process. It allows examination of the variation in treatment cost corresponding with an alteration in ambient environmental quality.

The model was applied to the San Joaquin River. It was able to produce results to within 5% of measured values obtained from the STORET computerized environmental data base (see Fig. 1). This information was applied in an assessment of ambient water quality impacts resulting from the siting of a hypothetical conventional generating plant along a given reach. The resultant temperature profiles are shown on Fig. 2. A sensitivity analysis was carried out as part of the assessment procedure. Outputs from the model may be displayed as one variable in a three variable interaction (Fig. 3). As shown, a biomass removal factor is plotted against plant characteristics (capacity) and cost of treatment. From this interaction the impacts of alterations in aquatic environmental quality may be directly expressed in terms of the

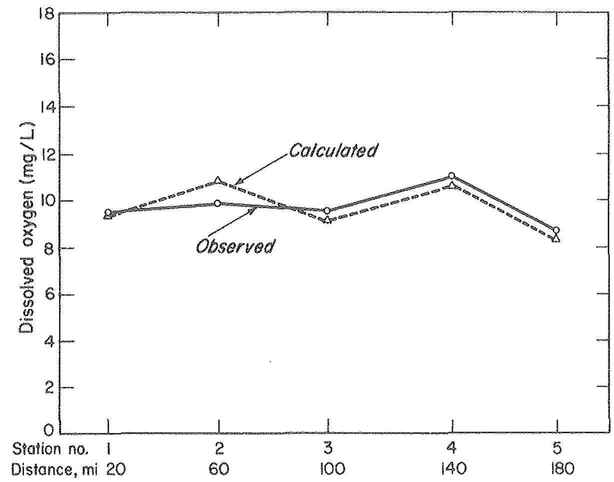

Fig. 1. Calculated vs observed DO levels in San Joaquin. (XBL 802-313)

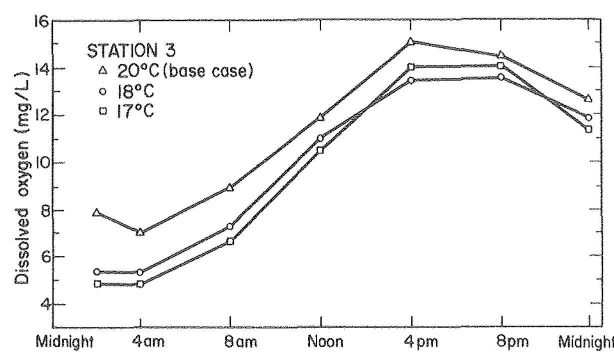

Fig. 2. Dissolved oxygen profile vs temp drop 5°C and alum coagulent addition. (XBL 802-314)

cost of compliance with existing or proposed water quality standards.

PLANNED ACTIVITY FOR 1980

The model developed here has the advantage of 'modular' construction. One is able to use parts of it to answer specific questions without neces-

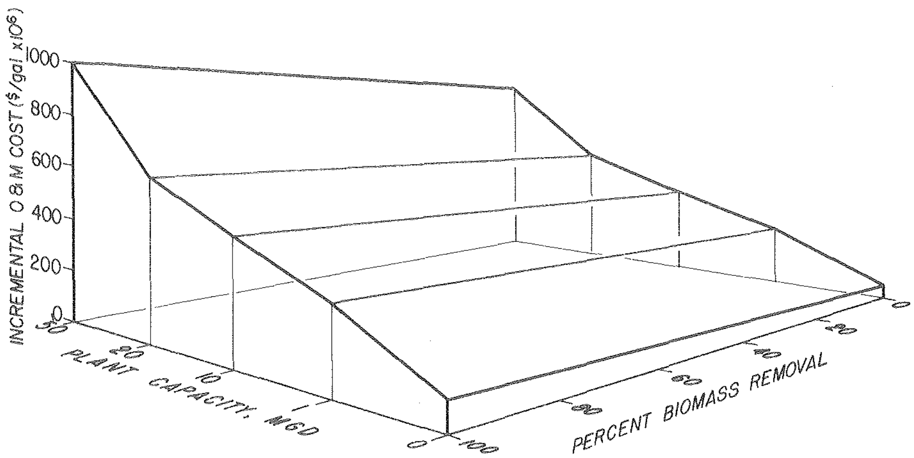

Fig. 3. Cost-treatment relations for photosynthetic oxygenation treatment processes where incremental cost to meet additional removal standards can be expressed $1/r_1-1$. (XBL 802-316)

sarily having to apply the entire model at once. The model is currently designed for application on fresh water aquatic systems.

The possibility of increasing model coverage even further by a more thorough treatment of the related engineering and economic factors is being studied. Additionally specific subroutines to address the flow and effects of pesticides are under study.

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REGIONAL ENERGY ISSUES: SUMMARY OF A WORKSHOP HELD AT LAWRENCE BERKELEY LABORATORY*

R. Ritschard and K. Haven

INTRODUCTION

The Energy Analysis Program at Lawrence Berkeley Laboratory (LBL), under Department of Energy (DOE) sponsorship, convened a one-day workshop in Berkeley on January 19, 1979. The primary purpose of the workshop was to identify from various perspectives the important energy-related environmental issues relevant to California, Hawaii and Nevada. It was not intended that all energy-related issues nor all perspectives within the region would surface in so short a time, but rather that the issues foremost in the minds of the chosen particpants would be identified and discussed. The participants represented the diverse views of state energy offices and regulatory agencies, the public utilities commission, utility companies, local government, several public interest groups and DOE.

The workshop was divided into four sessions. The mid-range/mid-term energy supply scenario for 1985 and 1990 was used as a framework for the conference, since the discussion of issues required some point of departure. The energy projections of the "mid-mid" scenario are based upon the recent forecasts of domestic energy supply and demand by the Energy Information Administration within DOE. The projections were disaggregated at the county level for Federal Region 9, which included California, Hawaii and Nevada.

Following a brief presentation of the energy supply scenario, a brain-storming session was conducted to identify a list of energy-related environmental issues. This initial list was discussed by two working groups, each consisting of eight participants plus an LBL facilitator and recorder. The mini working groups provided a description and definition of each issue from the perspectives of the participants. Finally, the workshop reassembled in a closing session to integrate and formulate the regional perspectives in a free and open manner. During these discussions, no opportunity was presented for the participants to modify the original list of issues.

Eight general issues were identified at the Regional Workshop. Some of these issues have sub-issues either related to their geographic specificity or to the nature of the topic. The perspectives of the participants on each issue are summarized below. Finally, a series of multi-issue conclusions are presented.

ISSUES

Nuclear Power in California

- Diablo Canyon. Substantial environmental opposition to licensing and operation exists.
- San Onofre. Thermal discharge questions may delay licensing.

Several distinct perspectives were presented on both the licensing of the two planned nuclear expansions and on the more general issue of the use and expansion of nuclear power in California.

The consensus was that both nuclear stations currently under construction will be licensed. It is less certain that they will actually go on-line as substantial opposition still exists within California. In either event, no additional nuclear plants will be built in this region (California, Nevada and Hawaii) within the foreseeable future.

Geothermal Energy Development in California

- Imperial Valley. Environmental issues may arise as development expands.
- Expansion in Geysers Area. Substantial environmental and socio-economic opposition exists to current geothermal expansion paths into Lake and Mendocino counties.

Geothermal development in both the Imperial Valley and the Geysers region will most probably proceed at a cautious pace. All parties agree that extensive commerically viable resources exist in both areas. However, technical and policital constraints will prevent widespread expansion over the near term.

Alternative Renewable Resource Technologies

- Less than one percent of the projected regional energy supply (1990) is attributed to renewable technologies.

Two distinct views were voiced concerning DOE support of renewable resource technologies. The first opinion was that DOE should greatly accelerate support of both development and commercialization of renewable technologies. The opposing view was that commercialization of any technology should be a function of the market place, not governmental policy. Neither view argues that solar technologies should not be developed. The issue is the rate of development and the respective roles of DOE and the private sector. It was agreed that the conversion of technologically feasible systems into "on-line" energy supplies is a major obstacle for solar technologies, and the federal government has little understanding of how to get a decentralized technology commercialized. Private and public sector cooperation will be required and it is unclear as to the role each should play in expediting the process.

Use of Natural Gas

- Increased reliance on natural gas is a reversal of past policies which shift from gas to oil and coal.

The discussion centered on the future need and source of California's natural gas. It was argued by some participants that the additional gas required to meet future needs would become available from fuel switching, conservation and increased domestic supplies resulting from price deregulation. On the other hand, some participants felt that increased use of natural gas will lead to increased imports requiring new pipelines and LNG terminals. Consensus was that an increased reliance on natural gas in this region could create substantial environmental problems if new sources and/or delivery systems are required. The primary issue is the siting of a LNG terminal especially related to who controls the siting decisions and where the facility is located.

Coal for Electricity Generation in California and Nevada

- Projections for coal use in California and Nevada were considered as unrealistic.

The major issue related to the use of coal in California and Nevada was that the mid-mid scenario did not reflect the current and future plans for electricity generation. In addition, there were several environmental areas perceived as possible impediments to future development of coal including air quality standards, transmission corridors and endangered species.

Energy Facilities Siting

- Conflicts exist between urban and rural siting of major energy facilities.

- Energy Imperialism. Local entities perceive a forced planning and siting of major energy facilities by federal governmental agencies.

No consensus was reached on these issues. The rural versus urban siting conflict is a major regional issue but does not directly involve DOE. The second issue includes important implications for federal energy planning. Local and Indian interest can influence the pattern of energy development in this region and therefore should be considered in federal energy planning and scenario development (bottom-up approach).

Conflict Between National Energy Plans and Regional, State and Local Environmental Goals

- Federal government does not always consider regional, state and local environmental goals, policies and regulations in planning national energy policy.

A theme that was expressed during the entire one day workshop was the need to incorporate regional, state and local information into the federal energy planning process. The "top down" planning process creates problems and antagonism at the state and local level with which the populace and governmental jurisdictions must live.

Institutional Issues

- Energy development is hindered by conflicts between regulations and regulators at local, state and federal levels.

- Energy development is delayed by the increasing amount of time required for a project to complete the regulatory process.

There was no consensus achieved on the resolution of these issues. It was agreed that additional effort by DOE to disseminate information to local public groups and potential intervenors and to increase involvement during the initial stages of energy planning (scenario development) will help. This type of involvement will bring the relevant parties, issues, and data into focus as soon as possible and thus minimize the potential for delays through last minute intervention.

CONCLUSIONS

By definition, an issue is a matter in dispute. It was the purpose of this one day workshop to identify the key issues confronting energy development in the region (California, Hawaii and Nevada). In addition to the issue-by-issue consensus reached by the participants, several general, multi-issue trends and conclusions were noted.

- There is a pervasive resentment of federal energy planning and intervention within this region. It was felt that the federal government has an obligation to support energy research and planning but this activity should be conducted at a state or local level. It is not appropriate for federal agencies to make decisions at a local level. They lack the site-specific data and perspectives required to produce effective, equitable decisions.

- There is a strong desire at the regional level to incorporate state and local planning into the federal planning process. However, there is a general lack of understanding of the mechanisms and contact points available to insert local concerns into the federal process.

- In general, the participants placed their emphasis on social and political solutions to issues rather than on technical ones.

- Significant intra-regional issues exist in addition to issues between regional and federal actors. Intra-regional issues are concentrated in the institutional and facilities siting areas.

- The general trends in regional energy development identified during the workshop are: 1) there is a high regional interest in solar/renewable technologies. Regional interest appears to be substantially higher than national in these technologies; 2) relative to other available fuels, e.g., fossil and nuclear, there are fewer major regional objections to expanded coal use; 3) no new nuclear facilities will be sited in this region in the foreseeable future; 4) expanded use of natural gas is desirable unless its use requires the development of new gas sources and delivery systems, e.g., LNG terminals, which can create substantial environmental impacts.

FOOTNOTE

*Condensed from Lawrence Berkeley Laboratory report, LBID-061 (June 1979).

NATIONAL/REGIONAL ENERGY-ENVIRONMENT MODELING CONCEPTS: SUMMARY OF A WORKSHOP*

R. Ritschard, K. Haven, H. Ruderman, and J. Sathaye

INTRODUCTION

On May 30, 31 and June 1 Lawrence Berkeley Laboratory, under the sponsorship of the Office of Technology Impacts (OTI), U.S. Department of Energy (DOE), held a workshop at Reston, Virginia on national and regional modeling. The workshop entitled "National/Regional Modeling Concepts for Energy and Environmental Analysis" brought together 35 experts from a wide range of disciplines including energy and economic modeling and several aspects of regional sciences.

The purpose of the workshop was to idenfity and evaluate approaches to regional economic and energy supply/demand forecasting that are best suited to assisting DOE in the assessment of environmental impacts of national energy policies. Specifically, OTI uses models to assess the impacts of technology change, to analyze differential impacts of various energy policies, and to provide an early warning system of possible environmental constraints. Currently, OTI employs both a "top down" model system to analyze national scenarios and a "bottom up" assessment conducted from a regional perspective. A central theme of the workshop was addressing the problem of how OTI should integrate the so called "top down" and "bottom up" approaches. To aid in resolving that problem, the workshop was structured to examine the experience of many fields of regional analysis.

The format of the workshop provided a flexible structure emphasizing small working groups. The first day of the workshop consisted of a plenary session which began with presentations that described the DOE/OTI policy impact assessment program and its goals and problems. After a brief discussion period, several different perspectives on energy and economic modeling were presented. The aim of these presentations was to examine the modeling experience in several fields of regional analysis and to focus subsequent discussion by the subpanels. The organization for the remaining two days, including the composition of the working groups and their general topic area, evolved from the presentations and discussions on the first day.

During the second session the participants were divided into three subpanels which addressed specific topics related to the overall objective of the workshop. The topics of the subpanels were: measurement issues and approaches, structure of models, and the application of models to policy analysis. The working group members were responsible collectively for developing a list of recommendations on their assigned topic during a day-long discussion period.

The last day was a plenary session in which each working group presented the findings of its discussion on the previous day. An open discussion period followed each presentation and provided an opportunity for further elaboration and refinement of the specific issues and recommendations produced by the workshop participants.

SUMMARY OF WORKSHOP FINDINGS

The goal of the workshop was to identify approaches for integrating the top-down and bottom-up methodologies currently being used by DOE/OTI. Several major problems which would limit using such an approach in energy policy analysis, described on the first day of the workshop, were discussed on subsequent days by the separate working groups. The conclusions and recommendations of each group are presented in order to address the overall theme of the workshop.

A need was expressed for both top-down and bottom-up approaches so that all interactions in energy-economic-environmental modeling systems could be adequately represented. For the short-term, recommendations were suggested for improving the current OTI models, but most of the comments were directed toward the development of a new methodology. It was recommended that a core set of related models be developed that are modular, dynamic and consistent; that have inter-industry accounting framework; that have inter-regional linkages; and that have adequate documentation. Further, it was suggested that an advisory group be formed to establish the appropriate methodological framework of the model system.

With regard to data used in any policy analysis model, it was recommended that OTI develop and maintain an integrated system of economic, environmental and energy accounts which is coordinated with the statistical agencies that collect the data. It was further suggested that an independent group be established to oversee energy data collection, coordination and verification. OTI can play a major role in ensuring that the data it needs for policy analysis models is collected and compiled in a suitable way.

The basic discussion regarding the use of models in policy analysis centered on the need for state and regional involvement in the assessment process. It was suggested that the state act as the basic geographic unit. State involvement was encouraged for use in the siting and disaggregation processes as well as in the interpretation and evaluation of the impacts. Further, there were several recommendations presented to improve the design of the assessment program. These covered the areas of energy and economic scenarios, cost of environmental standards, and the appropriate time frame for conducting a given policy analysis. Finally, it was emphasized that a closer relationship should be established between the decision-maker, the model and the modeler in order to guard against misuse of the model results.

In conclusion, five major themes emerged from the individual working group recommendations. These overall concepts seemed to dominate the discussions and may serve as the main conclusions of the workshop. First, the top-down and bottom-up approaches to policy analysis are compatible and can be used in an integrated fashion. Second, the methodology suggested for the integration process should consist of a core set of linked basic models with other special purpose models for specific assessments. Third, the data and models used in this methodology require review, verification and validation by outside groups. Fourth, regional and state involvement are necessary in any federal assessment process to enhance credibility and to increase accuracy. Finally, there is a need for a close relationship and communication between the decision-maker, the model and the modeler in order to maximize the proper use of the output.

FOOTNOTE

*Condensed from Lawrence Berkeley Laboratory report, LBID-078, draft.

CRITIQUE OF ENERGY INFORMATION ADMINISTRATION ENERGY SCENARIOS FOR REGION 9

J. Sathaye and A. Usibelli

INTRODUCTION

Each year the Energy Information Administration (EIA) of the Department of Energy is required to present a detailed Report to Congress. A large portion of this report consists of energy supply/demand scenarios output by EIA's Midterm Energy Forecasting System (MEFS). These midterm scenarios, covering the period from 1985 to 1995, are designed to portray a range of possible energy futures based upon variations in energy production, consumption, price, and related parameters. Output from the system is presented both in the form of national level projections and as regional disaggregations.

PROJECT OVERVIEW

The purpose of our study was to undertake a detailed examination of the MEFS output for Federal Region 9, (Arizona, California, Hawaii, and Nevada). The analysis is used by the Energy Information Administration as an aid in improving the quality of output from subsequent MEFS scenarios. LBID-133, "Region 9 Energy Supply Analysis", examined the supply component of MEFS in an effort to determine if the national forecasts for regional supply were in agreement with state and regional sources. Our analysis did not attempt to critique the models(s) used to derive the MEFS projections, but concentrated on the validity of the projections in view of regionally available information. Our work consisted chiefly of a search of energy supply literature published by agencies such as the California Energy Commission, the Hawaii Department of Planning and Economic Development, and a number of other public and private organizations. This material was supplemented by conversations with public officials and energy industry representatives.

Region 9 receives energy supply from a wide range of geographic sources both in and out of the region. Electricity is supplied from intraregional power plants and from imports from the Southwest and the Pacific Northwest. Oil is provided by indigenous California fields, Alaskan North Slope supplies, and numerous foreign countries. Natural gas, although produced in small quantities in California, is transported via pipelines primarily from the Southwest and from Canada. Coal, mined in fields in Arizona and several Rocky Mountain states, supplies a small fraction of total energy demand. This diversity of supply sources will increase in the future. The analysis concentrated on six major energy conversion/energy supply areas: electricity, refinery operations, new energy technologies, coal, natural gas, and oil supply. As an example of the type of comparisons made between MEFS and regionally derived estimates, Table 1 presents the natural gas supply projections made by MEFS[1] and the California Energy Commission.[2]

CONCLUSIONS

The Midterm Energy Forecasting System scenarios present a picture of increasing complexity in regional energy supply; however, our analysis found many of the specifics of MEFS scenarios in major disagreement with regional estimates. Some general conclusions of our report are:

- The MEFS supply projections for the region are overly optimistic. New electric generating facilities, refinery capacity additions, centralized new energy technologies (e.g. OTEC, STEC), crude oil from thermal enhanced recovery, and domestic natural gas supplies are from a few percent to many times greater than regional estimates.
- Price projections, especially for crude oil (a very significant parameter in the models) are underestimated by one-third or more.
- Regional supply projections are often based on outdated or erroneous information.
- Accurate supply (and demand) scenarios require much more careful consideration of regional level information.

Table 1. MEFS C-mid scenario projections (BCF/year)

Source	1985	1990	1995
Intrastate	238	275	304
NPC[1] 1N	245	245	332
NPC 1S	23	289	437
NPC 3	406	361	340
NPC 5	512	179	73
NPC 7	16	8	4
Other NPC 2, 2A, 4)	68	166	334
Canada	418	418	25
TOTAL	1,947	1,990	2,036

CEC[2] natural gas supply projections

Intrastate	117	73
El Paso (NPC 3, 5, and 7)	673	526
Transwestern (NPC 5 and 7)	106	107
Canada	348	73
Rocky Mts. (NPC 3)	37	62
PAC Interstate	9	11
Sub total	1,290	852
North Slope/LNG	220	365
Pan Alberta/Mexico	77	131
TOTAL[3]	1,587	1,348

[1]NPC = National Petroleum Council Regions
[2]CEC = California Energy Commission
[3]Total for California only. Supplies to Arizona and Nevada would increase regional projections by 10 to 15%.

FOOTNOTE AND REFERENCES

*Condensed from Lawrence Berkeley Laboratory report, LBID-133.

1. Energy Information Administration, Annual Report to Congress 1978, Volume 3.

2. California Energy Commission, Natural Gas Supply and Demand for California 1978-1900, p 180.

ENERGY ANALYSIS BY MEANS OF COMPUTER GENERATED INTERACTIVE GRAPHICS*

M. Henriquez

INTRODUCTION

In an age where resolution of complex technical questions is characterized by the use of large data sets, informational display in the form of interactive computer graphics has become an increasingly valuable research tool. The advantages of cartographic output over alternatives such as a tabular format for selected applications have increasingly become clear.

The primary value of maps is their ability to display clearly a number of different variables and their distribution in a form which is accessible to those who are neither familiar with nor involved in the original research.

This is not to suggest that the use of maps has totally eclipsed tabular or graphical displays. On the contrary, for any hand manipulation of data or in other cases where absolute values are desired, tables are inherently superior to maps. However, by making use of both options, a more comprehensive picture can be presented than the use of either option alone would allow.

GENERAL PROCESS DESCRIPTION

A collaborative effort by the Energy Analysis Program (EAP) and the Computer Science and Applied Mathematics Group (CSAM) at the Lawrence Berkeley Laboratory has resulted in a method for analyzing and displaying energy analyses. The software necessary for implementation has been undergoing various stages of development by CSAM over a period of years. The author, on behalf of EAP, has used the system extensively to accomplish his research objective.

The heart of the system is of the Socio-Economic Environmental Demographic Information System, or SEEDIS, an integrated system of data manipulation and display similar to an earlier version stored at the laboratory's computer center. From an applications point of view, this approach has allowed runs to be made in a fraction of the time and cost that would have been incurred with conventional methods. As many as 23 separate maps of a federal region by county have been produced during an interactive session lasting about one hour.

It is helpful to examine the steps necessary to produce a color map by this new system. First, one enters the interactive SEEDIS monitor to select the area and geographic level desired. The result of this step is a geocode file, which is used in subsequent steps to extract the data automatically and interface the selected information with previously created base maps which reside in the system. Possible choices for areas include one or more federal regions, standard metropolitan statistical areas, census tract, counties or water quality control regions, among others. Population limits on the desired area may be set at this time. It is possible to use either packaged data already installed on line as part of the SEEDIS monitor, or to insert original data to map onto the related geographic level. Examples of installed data bases include the Housing and Home Heating Characteristics data base developed by Brookhaven National Laboratory, the Federal Energy Regulatory Commission Electrical Generating Unit Reference File or the Populations at Risk to Air Pollution (PARAP) file. For example, data may be selected on the concentrations of specific airborne pollutants for the counties of California, along with information on death rates due to various forms of cancer for a given segment of the population. In some cases it is desirable to determine the ratio of two variables, and straightforward arithmetic subroutines are available for this purpose.

Having assembled the desired information, the user creates maps within SEEDIS, using the CARTE program developed by CSAM. The graphic files thus created are saved for additional processing, and are recorded on tape. The maps themselves are drawn by a Zeta plotter which is an output peripheral on the BKY system. Alternatively, the tape may be processed in such a way as to allow for cartographic output in the form of Dicomed transparencies. These transparencies are available in a variety of film formats and are characterized by intense color saturation and high resolution.

PROCESS APPLICATIONS

This process has demonstrated its usefulness in applications where a number of variables interact in a complex or synergistic manner. One example is in the case of certain water quality treatment problems which are usually impacted by energy technologies. Previous work[1,2] has shown such interactions involving the degree to which a given waste stream can be treated, the cost of treatment, and the size of the treatment facility. For any given treatment system, there will be a specific number of plants which may be located in a county to meet a given level of treatment. In evaluating the applicability of a given treatment technology to a county, it is helpful to know the number of separate plants that such a county can support. Competing factors in the selection of plant sites include population trends, land use patterns, and ambient environmental quality. Cartographic displays are an ideal way to present these diverse information files.

The relationships of cost, degree of treatment, and size of plant may be displayed as a two-dimensional representation of the relationship between these three variables and would take the form of Fig. 1. If a three-dimensional matrix is superimposed on the design envelope shown in Fig. 1, it is possible to define equi-distant points within the matrix through or near which descriptive curves for any treatment system must pass. Each point may be identified by a code specific to its location in

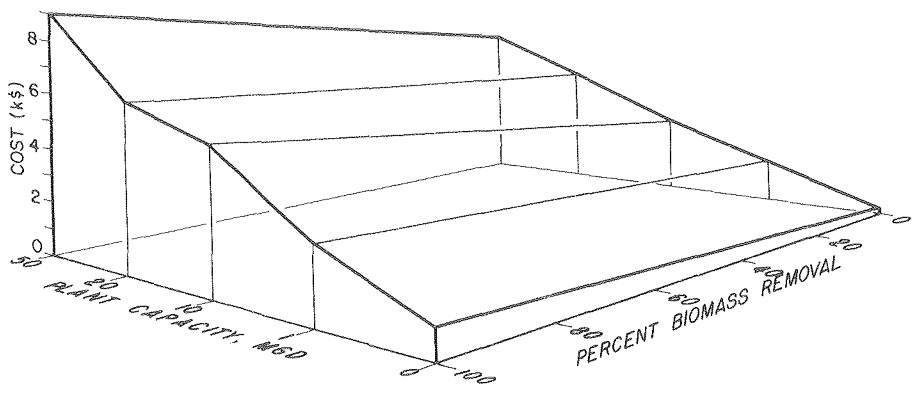
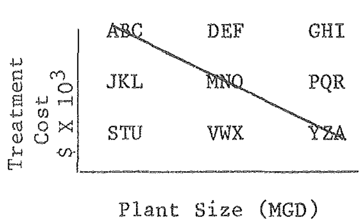


Fig. 1. Hypothetical relationship between cost, degree of treatment and size of plant for a photosynthetic secondary sewage treatment process. (XBL 802-315)

the matrix. Each location-specific code also identifies several frames of cartographic output which were constructed using data values valid for that point in the design space. By inputting two or more of the desired parameters (cost, degree of treatment, plant size) into a separate FORTRAN program, points in the matrix corresponding to points in the design curve are identified and the graphical information corresponding to the number of plants per county can be easily extrapolated.

For example, consider a specific treatment technology for which a linear relationship exists between the size of the plant and the cost of treatment over the interval of interest. Such a relationship may look like the curve pictured below and is shown in two dimensions for clarity.



By superimposing a variable matrix on the resulting design space, three points, namely ABC, MNO and, YZA, can be identified which are at or adjacent to the cost/size function. Location ABC may serve as the address for one or more frames of cartographic output; that is, it may define a unit of physical space on a data tape. This would show the number of treatment plants per county which may be sited if each of the plants operate within the extreme low range of plant size and the high range of treatment cost. The system described above may be expanded for three dimensions and would take the form shown in Fig. 2. This matrix is in the form for superposition over a design envelope.

This technique allows up to twenty separate frames to be stored per design point, or three variable addresses with the option of having each frame represent a multiple of the basic design space units. It is interesting to note that when the

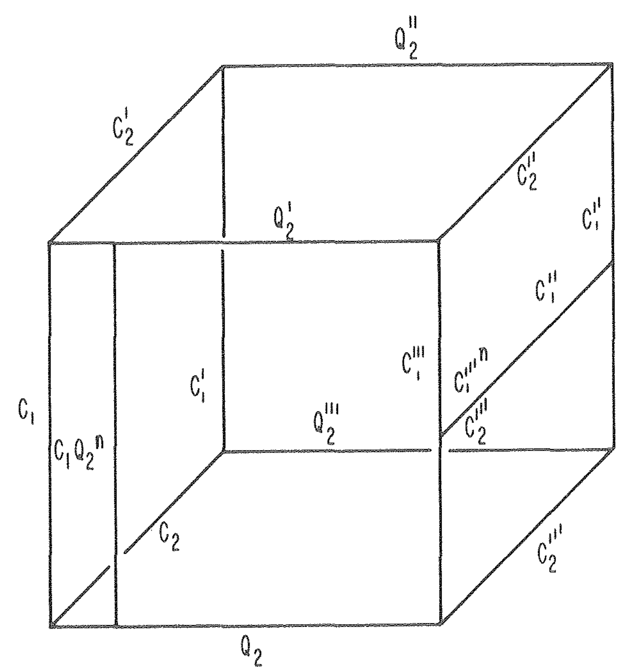


Fig. 2. Arrangement of individual addresses within a cartographic data storage matrix. (XBL 799-2867)

graphics data quantities are consistent with quantities derived from the characteristic engineering equations identified for a given system, proportionality between the engineering process and graphics data results. Because the maps themselves may be previously prepared, this system has applications in instances where users are lacking sophisticated computer skills. They need only identify system operation points to produce an array of the relevant cartographic data without actually constructing the maps.

PLANNED ACTIVITIES FOR 1980

Applications of the cartographic tools described in this paper are not restricted either to water quality or energy related applications. Many fields can benefit from interactive graphics. Additional applications within the field of energy development impacts using the PARAP data base are anticipated for inclusion in FY 1980 regional assessment efforts.

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THE HAWAII INTEGRATED ENERGY ASSESSMENT

J. Weingart, A. Ghirardi, K. Haven, M. Merriam, R. Ritschard, H. Ruderman, J. Sathaye, L. Schipper, and W. Siri

INTRODUCTION

The Hawaii Integrated Energy Assessment is a joint research activity of the Energy and Environment Division's Energy Analysis Program and the Hawaii State Department of Planning and Economic Development (DPED). The overall objective of the project is to assess the opportunities for and impacts of displacement of imported petroleum by use of indigenous renewable and geothermal energy resources in Hawaii over the coming quarter century. DPED began its work on this activity in late 1978. LBL cooperative research began late July, 1979. This report covers work through the end of FY79 and outlines the work planned for FY80.

BACKGROUND

Hawaii is dependent on imported petroleum for over 90 percent of its energy needs. The remainder comes primarily from the combustion of bagasse (sugar cane waste) in boilers for production of process steam and electricity. Total oil imports into Hawaii in 1977 were on the order of 40 million barrels or 8 GW(th), equivalent to roughly 1.5 percent of total U.S. oil imports (Table 1). Thirty-six percent of this is for jet fuel, which is not strictly considered a form of internal state energy consumption. The 1973 oil embargo was strongly felt in Hawaii and stimulated both public interest in and political commitment to development of Hawaii's seemingly abundant natural energy resources. A major element of Hawaii's energy policy has been the goal of reduction of the state's extreme vulnerability to disruptions in oil imports.

Table 1. Hawaii energy use, 1977.

	10^6 bbl/y	GW(th)
Jet fuel	14.3	2.88
Electricity	9.7	1.95
Other fuel	15.6	3.12
TOTAL	39.6	7.95

The indigenous energy resources include abundant sunshine (average insolation of 250 watts per sq. meter over much of the state), the trade winds, biomass, ocean thermal energy gradients, and geothermal energy. Some advocates for the use of renewable energy systems in Hawaii have proposed twin goals of electrical energy self-sufficiency by the early 1990's, and complete energy self-sufficiency by the beginning of the next centry.

It is widely agreed by analysts that the counties of Hawaii, Kaui and Maui (islands of Maui, Molokai and Lanai) could eventually become energy self-sufficient. However, 80 percent of the energy used in the state is consumed on Oahu, primarily in Honolulu. Energy independence for Honolulu, which in turn makes possible this goal for the entire state, will require a state-wide integrated energy system. This system would include inter-island transport of liquid fuels derived from biomass throughout the state, and possibly the electrical interconnection of some of the islands using undersea DC transmission cable. Existing cable technology would permit, for example, interconnection of wind energy "farms" on Molokai with Oahu; new technology would be required to permit use of Big Island geothermal systems as electrical sources for Oahu.

Project Context

While the focus of our work is energy independence for the state of Hawaii, the context of this effort is both national and global. No industrialized region in the world yet derives a substantial fraction of its commercial energy needs from renewable energy sources. This is in contrast to the economies of the rural regions of the developing world, which are almost totally dependent on biomass fuels. Interestingly, the urban regions of the developing world are very similar to the urban regions of the industrialized nations in both their reliance on high quality chemical fuels and electricity, and in their overall power densities.

Hawaii could become the first industrial region to make the transition to major or even complete reliance on a mix of renewable and geothermal resources. If this occurs, Hawaii could serve as a prototype for other island regions with similar energy resources (e.g., Puerto Rico, Micronesia, the Indonesian archipelago, etc.). We regard Hawaii as a potential "pathfinder" for the large-scale use of renewable energy resources for commercial energy production in both industrialized and developing tropical regions of the Pacific Basin, the Caribbean and elsewhere.

The implications are also important for the United States. The eventual large-scale use of renewable energy technologies for production of chemical fuels and electricity in the U.S. will require integration of these technologies into large, interconnected electrical networks and fuel systems. Hawaii seems likely to play a major role as a showcase and proving ground for development and test of renewable energy technologies. The technologies appropriate for Hawaii include biomass fuel production, and systems for production of electricity from wind, OTEC, photovoltaics, solar thermal electric systems and geothermal energy. Solar and geothermal energy can also be used as sources of process heat. Domestic solar water heating is already a well-established commercial activity in Hawaii. In a few decades, solar thermochemical and/or electrolytic production of hydrogen, and subsequent production of carbonaceous liquid fuels, may be technically and economically practical. By this route, Hawaii could eventually produce sufficient liquid fuels for all its energy needs, including those of jet aircraft.

Project Objectives

The objective of this joint research is to examine dispassionately the potential opportunities and costs associated with a transition to major or full independence of imported petroleum for the entire state through the use of indigenous energy resources. In particular, we are attempting to describe the evolution of an integrated energy system for production of electricity and chemical fuels over the coming 25 years. Other possibilities include importation of coal and/or coal-derived liquid fuels from Australia, Alaska, and the U.S. mainland. However, these are not being considered in this study due to funding constraints. The specific project objectives include:

1. Development of several scenarios for demand for electricity and liquid fuels by county, for the period 1980-2005.

2. Development of a scenario(s) for the transition to major reliance on indigenous sources of liquid fuels and electricity.

3. Characterization of the technical, economic, environmental and other aspects of a number of energy supply technologies essential for such a transition, including

   - solar water heating
   - hot water heat pumps
   - wind energy conversion for utility applications
   - solar thermal electricity
   - photovoltaics
   - liquid fuels from biomass
   - ocean thermal energy conversion
   - geothermal electricity and process heat
   - solar process heat
   - deep (2000m) undersea DC transmission cables
   - utility scale stationary battery systems

4. Calculation of the impacts of the supply scenario(s) on the labor sector, the environment and the state economy.

ACCOMPLISHMENTS DURING 1979

The initial efforts, carried out during the three month period of July-September, 1979 were aimed at developing a set of useful and Hawaii-specific technology characterizations for specific technologies, for creating a set of 25 years energy demand forecasts, and for a preliminary set of indigenous energy supply scenarios.

Technology Characterizations

Technology characterizations for solar water heating, wind energy systems, and biomass fuels in Hawaii have been completed and documented in a set of LBL reports now in press.[1-5] Additional characterizations for geothermal energy, OTEC, solar thermal electricity and photovoltaics are underway; technical reports on these will be completed in the first quarter of CY80. Additional technologies, including advanced stationary battery systems for utility applications and deep (2000 meter) undersea DC transmission cable technology, will be examined during CY80.

Some preliminary conclusions based on the technology characterizations completed to date are relevant. First, the potential role of solar water heating appears to be limited by competition from the hot water heat pump, which can displace similar amounts of electricity at a third or a quarter of the capital cost of domestic solar water heating systems (the latter costing over $3,000 for single family applications, before tax credits are applied). In any case, the ultimate displacement of total energy by solar water heating and heat pumps combined is only a few percent of the state's energy demand.

Second, the only solar electric technology available to utilities in commercial form in the next few years is large scale (multi-MW) wind generators. At expected installed costs of $1,000 per kW(e) or less, operation in a good wind regime (capacity factor of 0.3 to 0.5) permits displacement of oil for power generation. With a fixed charge rate of 0.15, the levelized busbar cost of electricity from wind generation would be equivalent to displacement of oil in the range of $20 to $35 per barrel. In the event that the installed costs of wind machines could, in mass production (several hundred identical units per year) be reduced to $500 per kW(e), oil would be displaced for an equivalent cost of $10 to $18 per barrel. Thus, in a utility system which is completely reliant on imported petroleum, partial displacement of oil by wind appears to be an economically and technically attractive option now, although the need to establish technical reliability and actual installed costs will inhibit massive installations of such systems for several years.

Third, any fuel-free technology capable of producing electricity from the sun at costs of under $5,000 per average kW(e) must be considered a serious contender. Such technologies include photovoltaics, solar thermal electric plants, ocean thermal energy plants (OTEC) and certainly geothermal plants, perhaps even future advanced systems designed to harness the energy in magma.

Solar thermal electric systems are projected to have capital costs (in current dollars) ranging from $1,000 to $3,000 per kW(e) at a 0.5 load factor in ideal sunny areas. With a 0.15 fixed charge rate, this corresponds to displacement of oil in the range of $20 to $60 per barrel. Some capacity credit is also possible. However, the European and American prototype STEC facilities coming on line in the next two years will cost $10,000 to $20,000 per kW(e). Commercial production of affordable plants seems unlikely before the early 1990's, and there is much less certainty than in the case of wind that economically interesting plants can really be produced. Nonetheless, the option appears potentially interesting for Hawaii.

Photovoltaic systems have systems goals of $1,000 per PEAK kW(e), equivalent to roughly $4,000 per average kW(e) in Hawaii. This corresponds to displacement of oil at $40 per barrel, and some capacity credit can also be assumed, depending on the extent of photovoltaic implementation. The cost goals are expected by those active in the photovoltaic field to be reached by the mid-80's. Again, we will not really know until the mid to late 80's what the commercial and technical characteristics of fully commercial photovoltaic power systems will be. As with STEC, the high conversion efficiency of the system makes photovoltaics an attractive option for a sunny, land-constrained region like Hawaii.

Geothermal energy is available primarily on the Big Island of Hawaii. The potential production rate is estimated to be in the range of 500 MW(e) to 2,000 MW(e). More exploration is required to determine this. Uncertainties in the lifetime for a plant built in the Big Island rift zone and the lack of large markets for electricity on the Big Island will constrain both the rate and scale of geothermal development. DC cabling to Oahu will require new cable technology which may be available late in this decade or early in the next.

Energy Demand Projections

An Energy Demand Forecasting Model was developed by DPED and subsequently modified through joint LBL/DPED efforts. This tool is an econometric-based simulation model designed to generate annual consumption forecasts of various fuel types for each of the four counties in Hawaii, through the coming 25 years. The model comprises a set of equations that relate the demand for energy to price, income, and other endogenous economic and demographic variables. Using forecasted values of the endogenous variables, the model forecasts energy consumption under the assumption that the coefficients in the equations will not change over the forecast period. The projected demands are then modified to take into account conservation measures such as anticipated improvements in appliance efficiencies and automobile gas mileage.

The model operates on a data base of historical time series data on the consumption and price of electricity, utility gas and liquid fuels. The data base also contains historical and projected data on demographic and economic variables such as population and income, visitor arrivals, and consumer prices. Prices for gasoline and imported oil were taken from the Department of Energy's series C forecasts. Electricity rates are generated internally in the model.

Such a model has its greatest utility when the future is expected to be much like the past. However, the unprecedented rise in oil prices and the rapid emergence of concern for conservation and increased energy efficiency requires modification of the model output. We have conducted an initial inquiry into the potential impact of increased energy efficiency on projected demands for various fuels and for electricity, whether from imported petroleum or from harnessing indigenous energy sources, will be much more expensive than energy savings through increased efficiency. An integrated energy strategy for Hawaii requires intensive efforts at conservation and improved efficiency coupled with development of indigenous energy resources.

The econometric forecasts for electricity and gasoline consumption were modified to take into account anticipated improvements in gas mileage and appliance efficiencies. No improvements in airplane efficiencies were assumed, since the new generation of widebody jets coming into service in the 1980's (e.g. Boeing 757, 767) will not have the range to service Hawaii. Estimates of the national average automobile fleet fuel efficiencies were based on the Energy Policy and Conservation Act of 1975. The efficiency is assumed to increase from 13.1 mpg in 1978 to 21.1 mpg in 2005, a 61 percent improvement. The gasoline consumption for each year as forecasted by the model was modified by a savings factor derived from the mileage estimates to provide the total consumption. For electricity, demand was disaggregated and modest estimates for improved efficiencies (Table 2) were used to obtain total electrical sales for the coming 25 years.

Figure 1 shows the substantial reduction in projected electricity demand due to improved efficiencies. We expect that substantially greater savings are possible with a state-wide aggressive and cost-effective conservation program. Figure 2 demonstrates the enormous savings possible in gasoline with improved vehicle efficiencies. The possibility of reducing by roughly a factor of 2 the projected gasoline consumption at the end of the

Table 2. Honolulu County conservation factors.

	End Use Percentages	Reduction Factors for Projected Years 1985	1995	2005
Residential Rates	100.0%			
Lighting	8.0	90%	80%	80%
Heating and Cooling	(see misc.)			
Water Heating	40.0	80	50	25
Frost-free Refrigeration	16.0	87	71	57
Electric Cooking	15.0	90	80	80
Dryer	8.0	90	80	75
TV-Radio	5.0			
Dishwasher	3.0	90	80	75
Miscellaneous	5.0	95	90	90
OTHER RATES				
Lighting	29.7%	80%	75	70%
Miscellaneous	8.4	90	80	80
Pumping	5.2			
Cooling	31.7	80	75	70
Commercial Refrigeration	8.2			
Motors	5.8			
Water Heating	3.8	80	65	65
Frost-free Refrigeration	1.6	87	71	57
Cooking	1.4	90	80	80
Dryer	.8	90	80	75
Communication	2.5			
Radio and TV	.5			
Dishwasher	.3	90	80	75

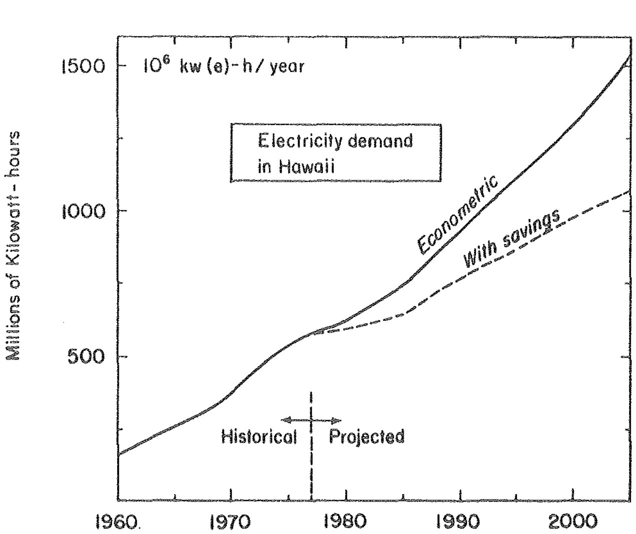

Fig. 1. Electricity demand in Hawaii.
(XBL 7912-13144)

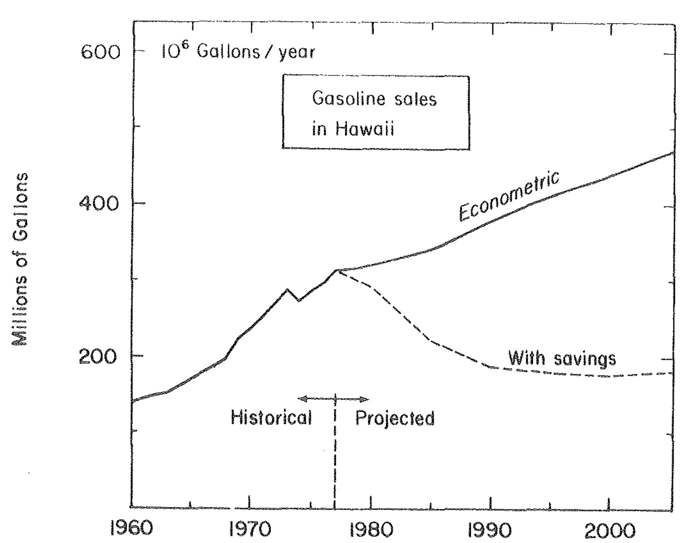

Fig. 2. Gasoline sales in Hawaii.
(XBL 7912-13145)

centruy is significant. It permits, in principle, the entire fuel requirements for ground transport to be provided by a biomass fuels industry in Hawaii. The unrestricted growth in demand for gasoline leads to a demand level which cannot, due to limits of available land and overall efficiency in production of biomass fuels, be met by a local fuels industry. Thus, conservation and improved efficiency will change Hawaii's energy situation in a qualitatively significant manner. Figure 3 shows projected demand for jet fuel. There is no way in which a biomass fuels industry in Hawaii could supply a substantial fraction of this demand. In the absence of high efficiency fuel production techniques (e.g. solar thermochemical or electrolytic production of hydrogen and liquid fuels), the jet fuel or its precursors must come from outside the state.

PLANNED ACTIVITIES FOR 1980

A one year continuation of the work (through 1980) has been funded by DOE for $170K, split equally between LBL and DPED. The major effort will be to develop a set of scenarios describing possible indigenous integrated energy systems which could be in place in Hawaii in 2005, and the paths for getting from here to there. Some preliminary assessment has been conducted during 1979. It is not possible to predict the future course of energy system evolution in Hawaii, availability of computer-based forecasting and other tools not withstanding. Our approach has been to identify to the extent possible the timetable for commercial development and the maximum rate of market penetration possible under various circumstances for the relevant energy technologies. In addition, we have compiled much of the available data on the extent and character of the various geophysical and biophysical resources in Hawaii. Preliminary scenarios have been developed for the maximum possible rate and scale of deployment of a number of technologies, including geothermal electricity on the Big Island, OTEC, wind energy systems, biomass fuels and solar water heating. Details appear in a forthcoming set of reports on the technologies[1-5] and on the project itself.[6-7] The scenarios are being developed through a series of workshops in which experts from industry, state and county agencies, the Hawaii Natural Energy Institute, the University of Hawaii, the utilities and elsewhere participate. Families of scenarios for the various technologies are emerging due to the dispersion in individual perspectives and assumptions. Our purpose in this process is not to attempt a forced convergence, but rather to display the range of possible futures over which informed individuals disagree. Making explicit this dispersion is an essential step in providing an informed basis for decision-making in Hawaii, and emphasizes the risk associated with premature foreclosure of options of large energy supply potential.

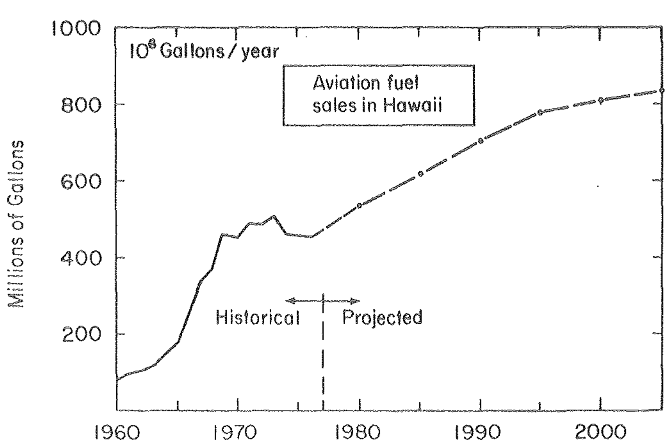

Fig. 3. Aviation fuel sales in Hawaii.
(XBL 7912-13143)

In addition, energy demand forecasts will be revised to take into account improved energy efficiency and conservation in a more detailed way than possible during the initial studies. Institutional issues associated with inhibition of stimulation of the large-scale use of indigenous energy resources in Hawaii will be examined, and the results of the entire research program presented to both specialists and the general public through an "outreach" program.

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Note: References 1-4 will be published as LBL reports in conjunction with the Hawaii Integrated Energy Assessment. Additional technical reports will be published by members of the HIEA team during the course of 1980.

ASSESSMENT OF SOLAR ENERGY WITHIN A COMMUNITY: SYNPOSIS OF THREE COMMUNITY-LEVEL STUDIES*

R. Ritschard

INTRODUCTION

The Office of the Assistant Secretary for Environment of the Department of Energy through its Division of Technology Assessments initiated a comprehensive project in mid FY 1978 relating to the extensive use of solar energy technologies. The project, entitled "Technology Assessment of Solar Energy Systems" (TASE), will determine the long-range environmental and socioeconomic impacts of solar energy systems. Since local or community impacts (e.g. land use, institutional requirements, etc.) may be greater than state, regional or national impacts with regard to solar technologies, a series of community level studies were initiated.

The overall purpose of the community level studies is to investigate the range of impacts of various solar-based energy systems on community environment, both physical and social. The studies also identify issues and constraits to local and regional deployment of decentralized solar technologies. The community level studies are divided into three task areas:

1. community impact analysis,
2. threshold impact analysis, and
3. solar city and state analysis.

The major findings of each study are presented in the subsequent sections followed by the general conclusions that emerge from the individual community-level studies.

COMMUNITY IMPACT ANALYSIS[1]

This study examines potential impacts of decentralized solar technologies on the physical structure of a community, that is, on its physical, spatial and land use characteristics. Land use types representative of those found in most U.S. cities were analyzed for the residential, commercial and industrical sectors according to the high solar use scenario, 14.2 quads of energy in the year 2000. Six different solar energy supply systems were examined, including thermal collectors of today's design and output with both short-term and long-term storage, thermal collectors with a 33 percent increase in efficiency using reflectors for both short-term and long-term storage, and cogenerating photovoltaic arrays with short-term and long-term storage.

Specifically, the analysis examines:

- the maximum on-site collector area for each land use type in the residential, commercial and industrial sectors;
- the land-use impacts likely to occur when achieving the scenario goal;
- characteristics of the natural and man-made environment which would effect the ability of the community to rely on decentralized solar energy technologies; and
- the percentage of each parcel's total on-site energy demand that could be provided by each solar technology.

The study team concluded that the high solar use scenario for the year 2000 is achievable without significant physical impacts. The decentralized technologies can, in many cases, produce substantially greater amounts of on-site energy supply than projected.

Only one land-use type, the commercial central business district, could not achieve solar goals on-site. The deficits, however, can be offset by the ability of other land-use types to supply increments of solar energy in excess of the levels projected. The team also concluded that low density single-family development (i.e., urban sprawl) is not required to meet the high solar scenario, but that industrial users in the central city would need to use cogeneration and biomass resources in addition to direct solar technologies to meet the high solar use projections.

The following activities were discussed as achieving a solar supply greater than that projected:

- use of long-term storage and cogenerating systems;
- use of shared energy systems including combined storage;
- transfer of surplus thermal and electrical energy to land-use types deficient in on-site solar potential;
- control of land development patterns eliminating characteristics that constrain on-site collecting; and
- the removal of 15 to 35 percent of the tree canopy in residential areas using on-site thermal collectors.

THRESHOLD IMPACT ANALYSIS[2]

The second community study examines potential community-level institutional impediments to the implementation of the dispersed solar technologies by the year 2000. The SRI team formulated a prototypical city of 100,000 population and projected a high solar use scenario to meet residential, commerical and industrial solar heat and electrical loads for the city. The team identified the institutions most likely to be involved with solar installations (utilities, financial institutions, community planning groups, construction industries, environmental protection organizations, special consumer groups, and legal and insurance interests) and described the complex ways they must interrelate to achieve the high solar use scenario by the year 2000. Also described was an array of institutional problems which can be expected to develop, in different degrees in different parts of the country, when solar technologies are implemented. This study provides background information from which national level policies can be formulated to achieve national solar energy goals.

Study findings are described in terms of two formats. The first uses three time frames to describe delays caused by the inherent difficulties a national energy policy would encounter in changing the ways in which community institutions respond to decentralized solar technologies. The second approach describes community-level difficulties associated with implementing each solar technology.

Three groups of institutional barriers were defined. Those barriers potentially causing 10 or more years delay concern:

- the rae of adoption of solar technologies by residential and commercial building industries;
- the rate of public and local government acceptance of new aesthetic standards;
- resolution of the legal issues of solar access easements, and the use of public funds for solar technology installations.

Other institutional barriers specified as more amenable to policy influence than those noted above, are in the 6 to 8 year impediment category and concern:

- financing;
- utility involvement with residential solar technology;
- cooperative neighborhood-scale installations; and
- the application of cogeneration technology.

Finally, in the 3 to 5 year delay category are barriers to solar technology development which are the most amenable to resolution including:

- performance warranties for complete solar installations;
- liability insurance for solar architects and engineers;
- solar technology standards;
- interfaces between solar technology owners and utilities;
- retrofit markets for homeowners;
- utility developments to accommodate solar owners for back-up service;
- small-scale distribution grids for cooperatives or neighborhoods;
- building performance applications as alternatives to building codes and specified insulation ratings;
- innovative planning at the community level;
- life style changes; and
- maintenance of a viable solar industry.

The second format describes the difficulties associated with the implementation of each solar technology. These include the complexity of installing approximately a million new solar space and hot water units and a million solar retrofits a year to reach the high solar use goal, and the extent to which utilities will be willing and permitted to participate in the installation, maintenance and control of solar equipment. The institutional impediments and problems of implemenation for larger scale technologies such as wind energy conversion, biomass conversion, photovoltaics and solar thermal were also briefly described and are similar to those found for solar heating and cooling. Included are problems of financing, siting, environmental hazards, legal and regulatory issues, and gaining the cooperation of planning agencies and local utilities. The SRI study team used all of these findings to emphasize the need for a strong federal policy on energy and solar technology to implement a strong national energy plan.

END STATE ANALYSIS[3]

The third community study investigates the structure of a typical community as it would appear in the year 2025 under varying solar growth scenarios, and examines the potential impacts on the physical form, environmental quality, socioeconomic structure and quality of life.

The UCLA team analyzed a hypothetical city of 100,000 after a period of growth based on three different energy scenarios:

- Future 1 specifies that 6 percent of the city's energy needs are met by solar technologies;
- Future 2 is based on 25 percent of the city's energy being supplied by solar technologies, where the city is dependent upon imported electricity;
- Future 3 represents a hypothetical city that is built to maximize the use of solar energy technologies.

All three scenarios are identical in terms of population and land use, goods and services produced, and energy demand and consumption. The hypothetical city was designed to reflect the median characteristics of existing U.S. cities, including prototypical building types in the three sectors, residential, commercial and industrial. Transportation energy use was excluded from consideration. The energy supply scenarios identified the energy supplied by each solar technology and the end-use demand for ech building type.

The study concluded the following:

- For all three solar futures, there would be potentially no significant increase in environmental impacts.
- The major noticeable aesthetic impact would be considerable increase in the amount of roof space covered with solar collectors.
- In Futures 1 and 2, all on-site energy requirements for the residential, commercial and industrial sectors could be met.
- In Future 3, the commercial sector would require the doubling of photovoltaic arrays and an additional 650 acres of land to be energy self-sufficient.
- In Future 3, the industrial sector could collect 18 percent of its energy needs on-site, but would require an additional 2800 acres of land to meet all of its energy needs.
- In Future 3, if the land area of the city were increased 34.5 percent, all three sectors of the hypothetical city could be energy self-sufficient. The resulting energy self-sufficient city of 13,450 acres would still be less than the median area (14,780 acres) of 23 existing U.S. cities of approximately the same populations.

CONCLUSIONS

Several general conclusions emerge from the individual community-level studies. Even though each task area used a different study methodology and format, the results provide some generalized trends that should enrich the overall TASE analysis. The conclusions are related to the scenario and study assumptions and should be viewed as illustrations of potential opportunities and impacts and not as projections of a likely urban future.

Land Use Impacts

The first general conclusion is that a community can meet the on-site energy demands assumed by the scenario in all but the most dense land-use sectors (e.g. central business district). In the residential sector, however, this may require removal of 15 to 35 percent of the tree canopy. Further, it may be required that greater than 80 percent of the total area in the industrial sector and about 50 percent of the available commercial parking area be covered with solar collectors.

Community Expansion

Secondly, decentralized solar technologies can produce substantially greater amounts of on-site energy supply than was prescribed by the scenario. Greater solar development can be realized by using "shared neighborhood systems" and by employing passive design in all new buildings. As evidenced in the hypothetical "solar city" (Future 3), a community may become self-sufficient if the commerical sector is allowed to expand by 65 percent and the industrial sector by over 400 percent.

Institutional Impacts

A third conclusion is that various institutional impediments produce time delays in achieving acceptance of solar technologies within the structure. Most important among those barriers are the acceptance and adoption of solar by residential and commercial building industries, the legal issues of solar access, easements and use of public lands for solar installations, and the aesthetic concerns of the public and planning agencies. In order to meet the levels of on-site solar collection that are prescribed in this study, these impediments must be removed.

Building and Urban Design

A fourth general conclusion is that passively designed buildings in future residential, commercial and industrial sectors need not look different from existing versions that consume up to 25 times more energy. However, the overall appearance of a community with a high level of solar development resulting in large collector areas, tree removal, and community expansion may be quite different based on current urban design and aesthetic criteria.

Community-Level Planning

There are great opportunities for implementing decentralized solar technologies within a community. This implementation will require the integration of urban and energy planning at the local level in order to avoid potential aesthetic, institutional and land use impacts.

Federal-Level Planning

Although decentralized solar technologies can be implemented within a community with few environmental impacts, a new set of issues are created at the local level which federal policy makers are not accustomed to addressing. These issues may be quite diffeent than those raised by the utilization of more conventional centralized types. Therefore DOE should recognize that different approaches may be necessary when dealing with decentralized and centralized energy systems.

FOOTNOTE AND REFERENCES

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UTILITY SOLAR FINANCE: ECONOMIC AND INSTITUTIONAL ANALYSIS

E. Kahn

ACCOMPLISHMENTS DURING 1979

One generic approach to accelerating the widespread adoption of residential solar technology is the use of public utilities as financial intermediaries. Although substantial tax credits currently exist which might induce consumers to invest in solar technology, their effect has been limited. Tax credits have more value to upper income groups than to other classes of consumers as evidence shows that credits have been utilized to a greater extent by this group than by the population as a whole. Public utilities, on the other hand, offer a number of advantages as a vehicle for the widespread commercialization of solar technology in the residential sector. These include access to high-volume, long-term capital; an existing collection mechanism; an incentive to minimize long run marginal costs; and credibility in the energy marketplace.

Analysis of the role public utilities might play in the commercialization of solar technology has normative and positive aspects. The normative question is: should regulated utilities be allowed a role in the solar market? What are the dangers to society of such policies? The positive aspects center on the institutional arrangements and implementing mechanisms necessary to implant the desired utility role. The residential solar market does not exhibit the economies of scale that normally justify regulated monopoly. Moreover, there is the perception in some quarters that utilities would distort the solar market by their disproportionate influence. The anticipated dangers range from a tendency to over-price the technology to the opposite fear that they will subsidize it excessively from other operations.

Various regulatory arrangements are possible to limit the dangers of utility involvement in the solar market. Most of these dangers center around how the role of "ownership" for solar technology is different from that of central station power plants. Efficient use of residential solar technology depends on adaptation to localized, site-specific conditions. Utility investment in conventional plant and equipment benefits from standardization. Ordinary utility investment procedures may lead to inefficient solar installations. This kind of potential distortion can be remedied by limiting the utility role to financial mediation with a local solar contractor industry. Such a limitation also would tend to reduce unjustified cross-subsidization from other utility operations.

Constructing a solar finance program for a particular utility will require explicit consideration of local conditions. This can be seen most clearly when the question of utility subsidies for solar finance is considered. Because many residential solar applications are less expensive than their conventional alternatives, it is reasonable to allow some of these savings to be passed along to the solar user. One widely accepted criterion that can be used to evaluate the appropriate size of utility subsidy is the marginal cost minus the average cost limit. This criterion will protect the interests of utility customers who do not participate in a solar finance program. Accepting this for the moment, it becomes clear that each utility will have a different situation with regard to marginal costs, average costs, and their difference. Other local conditions must also be considered. These include economic factors affecting solar costs (local wage rates, utility tax policies, etc.) and climatological factors affecting solar performance and the durability of equipment.

The regulatory specification of a utility solar finance program is further complicated by demographic mobility. Most solar systems require at least ten, and more commonly, twenty years amortization to be cost-effective. Yet the average family changes place of residence every five or ten years. How should a finance program be structured to account for this fact? This is not a problem under ordinary utility capitalization. The cost of the solar system would be part of the rate-base, to be paid for by all rate-payers, regardless of whether the occupant of a given dwelling with solar changed or not. If the new occupant did not want a solar system for some reason, he need not move in to such a dwelling. Accepting the solar system as part of the dwelling would impose no cost on the occupant other than what he already bears as a rate-payer. Since ordinary utility capitalization of residential solar systems may be excluded for normative reasons, we must consider how a financing program might deal with demographic mobility.

Conventional finance involves the specification of an interest rate and an amortization period. It might be possible in particular circumstances to justify a subsidy to utility sponsored loans that would reduce the amortization period to the average turnover time of housing occupancy. If this is not possible, some arrangement must be made to liquidate the loan at the time of turnover or to provide for the new occupant to assume the unpaid balance. Since the latter alternative would place significant barriers on the transfer of property, it is likely to be opposed by the real estate industry if not the market at large. A particularly imaginative solution to this problem is embodied in the residential weatherization program adopted by the Pacific Power & Light Co. (PP&L). This program provides zero-interest loans to single-family homeowners for weatherization investment. The carrying costs of this capital investment are borne by the rate-payers as a whole. This subsidy passes the marginal cost minus the average cost criterion. When such dwellings change hands, the original owner liquidates the loan, and that amount is removed from the utility company rate base.

The PP&L plan was designed for conservation investment. Since the economic advantages of solar applications are typically less compelling, there is a question concerning the feasibility of such programs for utility solar finance. To investigate this question, a case study was made of the Pacific Gas and Electric Company. The results of that investigation showed that while solar hot water heating could be expected to be less expensive than the marginal cost of electric water heating, the appropriate subsidy criterion could not be met for a zero-interest loan program. By comparison, utility finance of weatherization for electrically heated houses passes the test easily. The result for solar hot water heating does not bar a utility finance program. One method for retaining the features of a PP&L-type program is to average solar hot water in with conservation. Such a program meets the appropriate subsidy test.

PLANNED ACTIVITIES FOR 1980

Future work on utility solar finance will assess the impact of such programs on the financial position of participating utilities.

FOOTNOTE

*Condensed from Lawrence Berkeley Laboratory Report LBL-9959

LOCAL POPULATION IMPACTS OF GEOTHERMAL ENERGY DEVELOPMENT IN THE GEYSERS-CALISTOGA KGRA*

K. Haven, V. Berg, and Y. Ladson

REGIONAL BACKGROUND

The Geysers region is a subregion of northern California which contains large amounts of commercially attractive geothermal resource and the only vapor dominated geothermal field in the United States. The subregion includes the Geysers-Calistoga, Lovelady Ridge, Knoxville, Little Horse Mountain and Witter Springs KGRA's (Known Geothermal Resource Areas) and is located in portions of Colusa, Lake, Mendocino, Napa, Sonoma and Yolo counties about 75 miles north of San Francisco. The five KGRA's include roughly 420,000 acres with close to 380,000 in the Geysers-Calistoga KGRA alone. The bulk of the region lies in Lake County but most of the development to date has occurred in Sonoma County, including over 600 MWe in 13 units operated by the Pacific Gas and Electric Company.

INTRODUCTION

A majority of the previous studies which have addressed geothermal development in the Geysers area have focused on the characteristics of the resource and its potential for generating electric power. A second series of studies (principally EIR/EIS's) have addressed in detail the environmental and socio-economic impacts of the construction and operation of a single plant. However, little effort has been put forth to assess the potential effects associated with enactment of a long term development scenario.

A major study program with this objective was developed by DOE. The program has been conducted through the regional DOE office (the San Francisco Regional Office) and through Lawrence Livermore Laboratory (LLL), the lead laboratory for geothermal energy assessments, and has included an initial overview program and a series of follow-on assessments.

An umbrella research plan for socio-economic impacts was developed by LLL to provide a comprehensive response to the issues identified by the overview program conducted during FY 78. This multi-year umbrella study plan identified research tasks in all areas of socioeconomic concern and is built on collaborative LLL/LBL efforts.

LBL undertook one element of this program during FY 79. The central goal was to assess county level population impacts resulting from probable future (1979-2000) geothermal energy development paths. LBL task efforts included the development of electric and non-electric geothermal scenarios, the evaluation of existing county population growth trends, and the estimation of geothermal impacts on those growth trends.

GEOTHERMAL DEVELOPMENT SCENARIOS

Electrical Energy Production

The electrical scenarios developed for this study were conceived in a top down manner. Regional electrical production goals were forecasted based upon previous analyses and a set of scenario assumptions. Resulting totals were apportioned to counties as a function of KGRA potential.[1,2] and of existing development and drilling patterns.[2] Assumptions were made concerning the future split of steam flash hot water and binary hot water systems. Steam plants were limited to the existing steam field. System cost differentials were used to phase binary and flash systems into production as the steam field approached capacity. All scenarios recognized ongoing development activities and forecasted development as a function of a series of variables including energy price, water availability, activity in other geothermal areas, and ultimate capacity of the steam field, among others.

Two scenarios were selected for analysis: one describing a rapid geothermal growth rate, and one describing a slow growth rate. On line capacities for these scenarios are shown in Figs. 1 and 2. From the total capacities shown on these

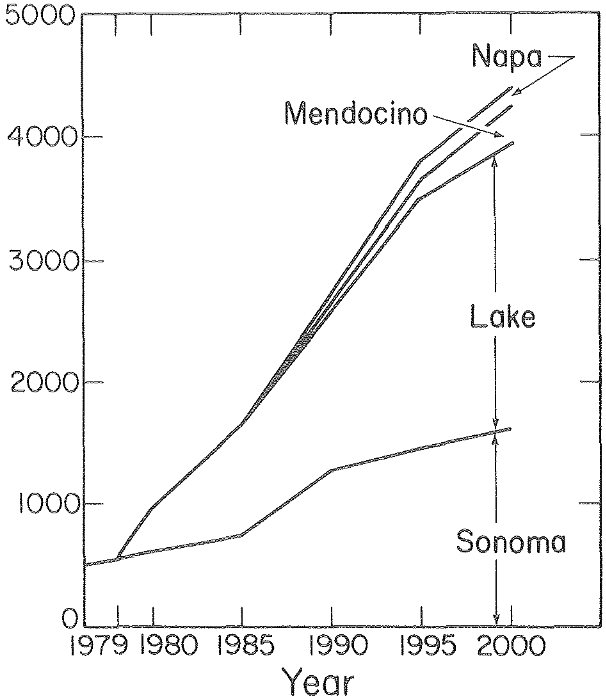

Fig. 1. County level capacity for the high growth scenario. (XBL 7911-13317)

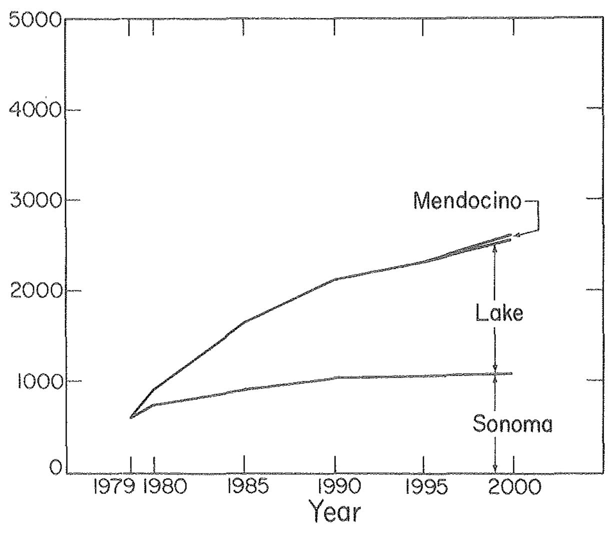

Fig. 2. County level capacity for the low growth scenario. (XBL 7911-13316)

figures, annual capacity additions, individual plant additions, and associated plant construction schedules and field development schedules were calculated. Data were obtained to describe industry employment patterns,[3,4] and total annual employment rates for the geothermal industry were calculated.

Sector multipliers calculated by PG&E for Lake County[3] were used to estimate indirect, or induced employment within the regional economy associated with geothermal development. Total employment (direct plus induced) was calculated for the region (see Fig. 3) and for the individual counties. The number of new jobs available each year was calculated and the portion of these available for non-residents (in-migrants) was estimated. Thus annual in-migrant workers and total in-migration rates were calculated for each scenario for use in population impact assessment.

Non-Electric Energy Development

Direct (non-electrical) applications of geothermal energy were investigated for the Geysers region. Successful operations in other areas have shown some potential for creating new jobs in geothermal resource areas. Direct uses were investigated from the viewpoint of the demographic impacts which might result from new employment opportunities. Direct-heat applications of geothermal energy which have the greatest potential for use in the Geysers area, including geothermally-heated greenhouses, crop drying, refrigeration systems and space heating were investigated.

While the opportunities for extensive direct use of geothermal resources in the Geysers region exist, direct-use applications have several characteristics which may result in a slow rate of market penetration. The most important of these is the requirement that the user be located at or very near the geothermal well site. Transportation and market location thus become important issues for the relatively remote geothermal resource areas. Other barriers to direct uses include the high capital cost of the systems, the depth of the local geothermal reservoir, the hard volcanic rock in the Geysers region, and a need for technology transfer to potential users.

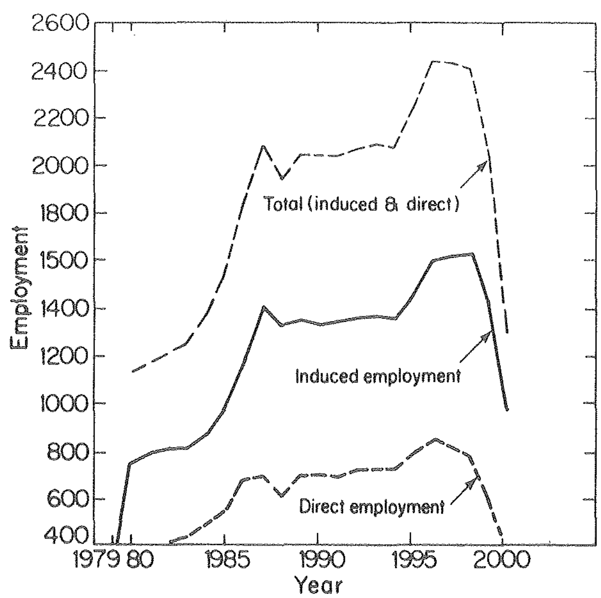

Fig. 3. Regional direct and induced employment for the high growth scenario. (XBL 7911-13315)

From the viewpoint of this study, an important characteristic of most direct uses is that they are capital-intensive and not labor-intensive. The result is that from 2 to 20 people may be employed for a few months to install the equipment, but very few, if any, permanent employees will be needed to operate and maintain the equipment.

In a probable development scenario, the first major uses of geo-heat in the Geysers region will be the retrofitting of existing public and private activities to use geothermal energy. In these cases, no additional (induced) jobs are likely to be created from the use of geothermal heat. A second stage of development will be the relocation of businesses into the Geysers region to take advantage of the geothermal resource. With the sole exception of greenhouse crop production, most businesses which could economically relocate to the rather remote geothermal area are small scale employers.

Under this scenario, both direct and induced employment opportunities created by direct use in the Geysers region are expected to be limited. A net increase in the order of 30 full-time employees in any one of the counties may be expected within the 1990-2000 time frame.

POPULATION IMPACTS

Net inmigration figures (direct and indirect employment plus dependents) associated with the high and low growth rate geothermal development scenarios are shown in Table 1. These inmigration figures were added to forecasted county inmigration rates for a "no geothermal activity" case and used to drive the State of California Department of Finance (DOF) population forecasting model.[5] This model is a county level cohort-survival model and is used for all state population projections.

Five runs were made on the DOF model for each county within the region: a "no geothermal" run, runs including only direct geothermally related inmigration for both the high and low scenario, and runs including both direct and indirect inmigration for both the high and low scenario.

The overriding general conclusion of the study is that geothermal energy development will not create major county level population impacts. Major specific conclusions of the study include:

- The course of geothermal development over the next five years appears to be relatively fixed and is not significantly affected by the major variables used in this study.

- The development of new employment opportunities within the geothermal industry occurs primarily when development first begins in a county. Subsequent capacity expansions tend to draw from the same labor pool with few expansions of the total in-county direct labor force.

Table 1. County level net inmigration caused by projected geothermal development.

	Low Growth Scenario				High Growth Scenario			
Year	Lake	Sonoma	Mendocino	Napa	Lake	Sonoma	Mendocino	Napa
79	522	744	0	0	524	743	0	0
80	520	558	0	0	697	858	0	0
81	225	-111	0	0	337	-125	0	0
82	159	-44	0	0	230	-68	0	0
83	103	-41	0	0	182	-16	0	0
84	-17	-9	0	0	326	21	0	0
85	-28	28	0	0	182	229	51	0
86	-38	-82	0	0	328	142	313	0
87	-57	-59	0	0	255	101	109	0
88	43	-96	0	0	139	33	57	0
89	49	-78	0	0	103	-53	57	0
90	-52	39	0	0	50	-77	10	25
91	-94	83	0	0	-76	-16	-32	271
92	+10	49	0	0	-9	-13	82	187
93	-28	-58	0	0	24	39	82	-58
94	80	-41	19	0	-62	155	44	-91
95	-18	-44	198	0	4	102	258	-32
96	-1	0	109	0	117	-18	161	153
97	-2	-8	-76	0	-36	-28	128	187
98	-69	0	-44	0	-23	31	64	-57
99	-11	0	-34	0	-133	-76	-124	-88
2000	-135	0	-16	0	-322	-230	-245	-51

- After the initial surge of inmigrants is over, geothermal construction activity fluctuations are likely to produce a net out-migration in a county in any given year as it is to cause a net inmigration.
- While both are small, the indirect labor force expansion and associated in-migration is substantially larger than that of the direct labor force.
- Direct use of geothermal energy may cause a few key industries to expand but the overall direct and indirect population impacts will be very small.
- The county appears to be an inappropriate scale for the identification of demographic impacts from geothermal development. Sub-county geographic units (e.g., Cobb Valley) or individual communities appear to be the scale on which impacts may be felt.
- Any inmigration impacts from geothermal development have already occurred in Sonoma County, are nearly complete in Lake county, will probably occur in the late 1980's in Mendocino County, and will occur after 2000 if at all in Napa County.

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CONSERVATION STRATEGIES FOR COMMUNITY COLLEGES

B. Krieg and C. York

INTRODUCTION

In FY 1978 a pilot project to develop strategies for energy conservation was carried out with five Community Colleges in Northern California. The strategy was based on a program, called TEEM, which had been used by PG&E in K-12 schools in the Fresno area.

In the Total Educational Energy Management (TEEM) system of energy conservation and management, each campus building and activity is considered as a unique system which uses energy to fulfill the specific needs of educational programs. The TEEM system, flexible by design, provides a framework within which the campus community can systematically consider and implement a great number of effective energy-saving practices.

The TEEM system has two basic objectives:

1. Reducing campus energy requirements, and
2. Meeting those reduced energy requirements without adversely affecting the quality of educational programs.

Initially the TEEM system is a labor-intensive approach which required the commitment and participation of all segments of the campus community. The faculty, student body, administration, staff and governing board must be organized into an effective team to analyze and implement energy-saving measures. The TEEM approach provides this essential organization of the campus community.

To begin the process, the president of the college must adopt the concept of an energy management program. Once the president is willing to commit his institution to such a management program, he must take two actions. First, he must request his governing board to declare, as a matter of policy, that energy conservation on campus will be a high priority. Second, he must appoint an "Energy Conservation Task Force", which is representative of all segments of the campus, to develop and carry out a program for conserving energy on the campus.

Following this simple start, the pilot project was able to demonstrate a "cost avoidance" of \$300,000 in the utility bills of the five campuses involved. Table 1 shows the detailed savings for each school. DOE asked LBL to establish a national program in FY '79 and '80 to attempt to achieve similar results across the country.

ACCOMPLISHMENTS DURING 1979

If the results of the five college pilot projects could be equaled by all 1230 two year colleges in the U.S., then an annual savings of about 1/30 of a Quad, or 33 x 10^{12} BTU per year could be anticipated. To achieve this, LBL was asked to launch its national effort at a special workshop of the National Education Business and

Table 1. Program Summary: Energy and dollar savings.

From: Budget year April 1976 - March 1977
To: March 1977 - April 1978

College / Fuel Type	Diablo Valley Community College	Indian Valley Colleges	College of Marin	Santa Rosa Junior College	Sierra Community College
Electricity					
Savings (KWH x 10^6)	1.083	1.300	0.776	0.317	1.382
Use '77-'78	9.604	2.611	5.986	4.489	4.333
Savings (BTU x 10^9) Thermal Fossil Fuel Equivalent	11.10	13.31	7.94	3.25	14.16
Gas					
Savings (Therms x 10^3)	6.850	-19.88	193.3	87.95	131.6
Use '77-'78	52.65	82.80	468.0	356.0	227.4
Savings (BTU x 10^9)	0.685	-1.988	19.33	8.79	13.16
Total Cost Avoidance	$47,140	$57,550	$75,790	$32,830	$97,400
Fuel Cost '77-'78	$414,580	$141,600	$371,700	$273,140	$260,890
Percentage of Total Fuel Cost	11.4%	40.6%	20.4%	12.0%	37.3%

Labor Conference on Energy-Related Vocational and Technical Training, Employment and Public Awareness, which was held in Washington in January 1979. The plan was to collaborate with one of the national organizations of the community colleges. The work was to be divided by having this organization serve as the contact with the colleges and LBL would provide data analysis and similar technical support functions. The League for Innovations in the Community Colleges in Los Angeles was chosen as the organization and in March of 1979 contacted all 1230 two year colleges to invite them to join in the project. 304 colleges from all over the country have agreed to participate. In October of 1979 these participants are to submit data on their utility bills from the previous years, 1978-79, and the first six month period of the operation of their TEEM program of energy conservation. 128 colleges have actually submitted this data.

PLANNED ACTIVITIES FOR 1980

The first six months of data will be analyzed and reported to the participating colleges. Computer programs to calculate energy savings and cost avoidance from the submitted data have been written and are in operation. In March 1980 the colleges will submit their utility bill data to determine the effectiveness of their campus programs. We hope to publish the results of these analyses in the Summer of 1980.

INTERNATIONAL RESIDENTIAL ENERGY CONSERVATION

L. Schipper

INTRODUCTION

The Lawrence Berkeley Laboratory has begun to collect and analyze data on residential energy use for seven countries (Canada, France, West Germany, Italy, Japan, Sweden and the United Kingdom) as part of a project sponsored by the Energy Information Administration. The purpose of the project is to improve our knowledge of future energy demand and conservation opportunities in other countries, as part of our effort to understand the dynamics of the demand for internationally traded fuels, like oil (see Ref. 1 for related analyses).

The first paper in this project, "International Analysis of Residential Energy Use and Conservation," (LBL-9383), was prepared as a preliminary discussion of work done through the summer of 1979. The paper is published in the proceedings of the Second International Conference on Energy Use Management (Pergamon Press, 1979). The paper describes the general problem of analyzing residential energy use in different countries.

PROJECT OVERVIEW

Residential energy use is analyzed in terms of both a vector of end use activities (e.g., cooking, space heating or cooling, etc.), each of which is measured in physical terms, and of energy intensities that express the energy requirements at the point of use for each unit or activity (Table 1). Additionally, the analyses are segregated where possible by fuel type, though an aggregation will be made at the end of the project. In addition to gathering data on specific energy uses, the first two work tasks included the collection of basic economic and demographic data. Economic data, such as personal disposable income or consumer expenditures, are important for understanding the economic forces that have driven the demand for residential energy use. Demographic information on housing (particularly the size and structure of the housing stock) and population characteristics are very important for quantifying the demand for space conditioning. Thus far we have assembled details of the housing stock, including the size of typical multiple and single family dwellings for many years throughout the study period.

By examining changes in both the structural factors and in energy intensities, the role of each kind of factor in contributing to changes in energy use can be quantified. Additionally the potential for conservation through reductions in energy intensity can be evaluated, and energy uses can be projected based upon a very disaggregated model of demand that takes saturation, conservation, and the effect of energy prices and policies into account. Finally, the relative importance of all the factors that shape energy demand in various countries can be compared. Table 1 lists some of the major energy demands that are being investigated, and gives both measures of intensity sought, and the structural components relating to economic activity and, where appropriate, to lifestyle or behavior.

Some of the factors that are more easy to quantify include a measure of heating degree days (though conventions vary from country to country), income, house size, indoor temperature (as inferred or measured saturation of appliance stock, and energy prices. Some of the more difficult factors to quantify, or factors for which data is difficult to obtain, include appliance utilization, appliance prices and actual sizes, and the actual split between heating and non-heating uses of fuels.

Indeed, the quantification of each end use has specific problems. When calculating space heating requirements, it is desirable to know the contribution of non-heating appliances (people, the sun, other appliances, and hot water) to the heat balance of the house since extremely well built houses replace most of their heat losses from these sources. In a related project,[2] the factors that account for space heating and conventions for measuring them are discussed. Even though cooking now represents a relatively small energy end use, it is desirable to know the relative intensities of electric and gas stoves, the number of meals eaten in the home, and the nature of a country's cuisine in order to really understand this use of energy. Hot water, however, usually ranks second to space heating for total energy consumption but is relatively poorly understood. In some cases, estimates were found of hot water consumption (in liters/year) and temperature, enabling a careful estimate of energy intensity to be made. In most cases, however, we had to settle for a measure of the average amount of fuel used per device, and the number of devices of each kind in each home as a measure of hot water energy use.

Appliances have been a growing end user of energy with the rise of personal incomes in the study countries between 1960 and 1975. Though there is important evidence of saturation in the ownership of some major appliances (e.g., refrigerators, televisions and clothes washers) in the near future, others (freezers, clothes dryers and dishwashers) are still relatively unsaturated. Utilities have kept relatively detailed statistics on appliance ownership, and some information on appliance size is available. Furthermore, in every country, estimates of unit consumption for each kind of machine are available. Typically these estimates can account for 90 percent of the residential electricity use.

PLANNED ACTIVITIES FOR 1980

The project has completed the tasks of gathering and submitting economic and demographic data, though some holes in the information still remain. Present activity centers on analyzing the time series of consumption data, on comparing different estimates of end use consumption, and on making

Table 1. Characterizing residential energy use.

Activity	Range of Residential Use	D: Structure	D: Behavior or Lifestyle	E: Intensity
		MIXED USES		
Space Heat: House	40%-80%	House Size, Type	Indoor Temperature, Fraction of House Heated	Q/m^2 - DD
Space Cooling	~5%(Japan, US) ~30%(warm US)	House Size, Type	Indoor Temperature, Number of rooms cooled	Q/m^2 - DD
Space Heating System		Saturation of Central Heat by Fuel		$\frac{Q_{delivered}}{Q_{consumed}}$ "First Law Efficiency"
Space Cooling System System		Room or Central		$(\dot{Q})_{out}/\dot{Q}(electric)_{in}$ EER
Hot Water	5%-30%	Type of Equipment, Saturation, by fuel	(Liters/yr) Outlet temperature	$\dot{Q}/(1) \times (\Delta T)$
Cooking	3%-6%	Equipment Saturation, by fuel	Meals cooked/yr.	Q/yr Presence of other fuel or electric cooking devices
		ELECTRIC USES ONLY		
Refrigeration, Freezing	3%-6%	Saturation	Size, Options	Q/yr
Television	≤2%	Saturation	Size, Options, Hrs/yr	$\dot{Q}$ watts
Dishwasher	~2% + H_2O	Saturation	Size, Options, Hrs/yr	Q/load Source of hot water?
Clotheswasher	~2% + H_2O	Saturation	Size, KG/yr	Q/KG Source of hot water?
Dryer	~2%	Saturation	Size, KG/yr	Q/KG Use of sun

NOTE: Q measures energy; $\dot{Q}$ measures power (energy time); DD - degree days; m^2 - dwelling floor area; L - H_2O consumption, refrigerator volume; KG - weight of clothes; ΔT - temperature difference

estimates of actual consumption of each form of energy for several years (1960 or '62, '65, '68, '70, '72 and '73-'77). We have been aided by the publication of several important studies in Italy, the United Kingdom and France since the commencement of our work, and intend to make several more in-depth contacts with correspondents in Europe and Japan before submitting final energy use data.

Once data have been accepted, we will compare energy use in each country from before and after the 1973 oil embargo, relating energy use changes to changes in prices and conservation policies. We will attempt to make judgemental forecasts of residential energy use in anticipation of a later effort directed at building a set of residential energy use scenarios for the year 2000. This task will be undertaken in cooperation with a group at the Institute Economique et Juridique d'Energie at the University of Grenoble, France, which is making a similar effort to analyze residential energy use in the Common Market countries.

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*Condensed from Lawrence Berkeley Laboratory report LBL-9383.

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OVERCOMING SOCIAL AND INSTITUTIONAL BARRIERS TO ENERGY CONSERVATION*

C. Blumstein, B. Krieg, L. Schipper, and C. York

INTRODUCTION

Energy conservation is becoming an increasingly important response to the continuing energy supply crisis. A persuasive case can be made that conserving energy by increasing the efficiency energy using devices and practices is less expensive than finding additional new supplies of energy. Many energy conserving actions can, in fact, tend to maximize well-being and minimize sacrifice and social cost.[1]

Although they are economically rational responses to the energy crisis, energy conservation actions may be hindered by social and institutional barriers. In the research reported here we explored the nature of these barriers and examined some of the strategies that could be employed to overcome barriers. A more complete description of the results of our research can be found in a Lawrence Berkeley Laboratory technical report.[2]

THE NATURE OF BARRIERS

Although barriers to energy conservation are not an altogether new topic for policy analysts,[3] previous studies have devoted very little effort to systematic study of the problem. Therefore, we began our effort by defining and classifying various types of social and institutional barriers to energy conservation. Six classes of barriers that occur regularly were identified:

Misplaced Incentives. The economic benefits of energy conservation do not always accrue to the person who is trying to conserve. For example, if an apartment tenant pays the utility bill, the landlord has little incentive to make energy conserving improvements.

Lack of Information. The efficient working of the market depends on the parties to transactions having adequate information. If a consumer is unaware of the cost effectiveness of a conservation measure, he is unlikely to adopt the measure.

Regulation. If a cost-effective conservation measure conflicts with existing codes or standards, its implementation will be difficult or impossible.

Market Structure. Even though a conservation measure or device is cost effective, it may not be on the market.

Financing. Energy conservation measures often require an initial investment; thus the unavailability of financing may be a barrier to some cost-effective measures.

Custom. If a cost-effective conservation measure requires some alteration in the habits of the consumer or seems contrary to some accepted value, such as being considered something that only people of low social status do, it may be rejected.

To gain further insight into the nature of barriers to energy conservation we conducted a series of interviews with people in the building sector: landlords and managers of residential property, managers, owners, and operators of commercial property; and other people connected with the buildings sector such as realtors, representatives of trade associations, and contractors. The interviews (reported in detail in Ref. 2) revealed a variety of views and perspectives. However, some common themes did emerge. A concern with costs was coupled with a lack of information on what the costs are and what the effects of conservation might be. The problem of misplaced incentives recurred in many forms.

STRATEGIES FOR OVERCOMING BARRIERS

While our study of the nature of barriers did not provide a complete picture of the complex issues involved, we felt that it did provide a starting point for examining possible strategies for overcoming barriers. We identified six types of strategies:

Informing. Where lack of information is a barrier to energy conservation, actions can be taken to provide information in several ways. New information can be produced by sponsoring research; the flow of existing information can be facilitated by supporting libraries and indexing services; and information can be communicated directly to users by providing education and training.

Leading. Energy conserving behavior can be encouraged by leadership. This can be done by example such as the President turning down the White House thermostat, or by persuasion such as the familiar "Don't be Fuelish" advertisements.

Market-Making. A number of actions can be taken to create markets for energy-conserving products or services. Government purchasing policies can be directed toward encouraging the production of energy-efficient products. The government can also create markets in the role of entrepreneur, undertaking development and demonstration projects.

Rule Making. Regulations can be used to encourage or compel energy-conserving actions. For example, rules can require that all residential property be insulated before it is rented or sold.

Pricing. Government policies can influence the incentives to consume or conserve by changing the net price of energy or of energy consuming and conserving commodities. This may be done directly as a seller (of enriched uranium, for example) and by price controls, or indirectly through taxes and subsidies.

Rationing. In principle, the government can use rationing to conserve scarce resources by limiting consumption to some predetermined "correct" value. However, in practice, rationing is usually used to allocate scarcity: when some commodity becomes scarce, and particularly when the scarcity is dramatic and sudden as in times of war, society may choose to ration the commodity in preference to allowing the price to rise.

In addition to identifying and describing strategies, we developed some criteria for evaluating them. These criteria were divided into two classes: those that relate to the efficiency of a strategy in achieving the goal of energy conservation, and those that relate to the impacts of a strategy on other (possible competing) economic and social goals. In the former class we included such factors as direct costs and benefits, political feasibility, ease of implementation, and leverage. In the latter class we included impacts on economic growth, income distribution, employment, land-use patterns, lifestyle, and individual freedoms.

RECOMMENDATIONS

We concluded our work with three recommendations for action directed at overcoming barriers to energy conservation:

Information Programs. We believe that lack of information is a serious and pervasive barrier to energy conservation and that enchanced information programs are one way to attack this problem. One area in need of increased support is the Energy Extension Service.

Demonstration Projects. Many of the possible actions which could be taken to overcome barriers to conservation have a high risk of failure. We believe that before such actions are taken on a national scale, they should be tested in local demonstration projects. The Federal government should assist such projects by providing financial support.

Futher Research. The nature of barriers is still incompletely understood and sound systematic methods for evaluating strategies are not well developed. Further research is needed to provide greater understanding and improved methods.

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ENERGY POLICY DECISIONS AND CONSUMER DECISION-MAKING: APPLICATION TO RESIDENTIAL ENERGY CONSERVATION

*J. Corfee, M. Levine, and G. Pruitt**

INTRODUCTION

The National Energy Conservation Policy Act (NECPA) mandates that Appliance Energy Efficiency Standards be prescribed by October of 1980.[1] The law requires that the Standards be designed to achieve the "maximum improvement in energy efficiency" that is "technologically feasible and economically justified." Determination of the economic justification must be based on: the savings in operating costs over the average life of the appliance compared to the increase in the initial purchase price or maintenence costs likely to result from the imposition of the standard; the economic impact of the standard on the manufacturers and the consumers of the appliances; the total projected energy savings likely to result directly from the imposition of the standards; and other relevant factors. Clearly, it is necessary to develop appliance standards that achieve minimum life cycle costs and to evaluate the total impact on residential demand resulting from the implementation of the standards.

The Appliance Efficiency Performance Standards (AEPS) project at LBL will analyze residential energy demand in support of the appliance standards as outlined in NECPA. The primary tool of the demand analysis will be the ORNL Engineering-Economic Model of Residential Energy Use,[2] which provides detail on the energy use of eight major end-uses by each of four fuel types in the residential sector. Primary in the model are the consumer decision making algorithms determining the saturation of new technology and ultimately the energy use of the appliance stock. Unfortunately, it is the consumer decision algorithms that are considered a major weakness and the least empirically validated components of the model. As a result, a specific research task of the AEPS project has been to improve the consumer decision algorithms of the ORNL model.

ACCOMPLISHMENTS DURING 1979

This paper describes the consumer decision research task. Specifically, two methods for improving the ORNL model are described, followed by a summary of preliminary analysis of the refrigerator market in the United States.

Methods of Improving the ORNL Consumer Decision Algorithms

As previously noted, the consumer decision algorithms are a critical weakness of the ORNL model. Two methods of improving or creating new algorithms are detailed here. The first approach represents an attempt to discover the average effective discount rate used by consumers in their appliance purchases. Ultimately, changes in the average effective discount rate over time indicate the response of consumer decision making to changes in fuel prices. The second approach is an attempt to determine econometrically a meaningful consumer decision algorithm. Both methods focus on the importance of operating costs versus the purchase price in consumers' decisions to buy an appliance.

Method 1

The first method of discovering consumers' average discount rate is a straightforward life cycle cost calculation. However, there is an assumption that the purchse price of the appliance is a function of the product energy efficiency. It is precisely this assumption to which the refrigerator analysis, described in the next section of the report, is devoted.

A simple form of the life cycle cost equation is:

$$LCC = FC \pm \sum_{i=1}^{N} [(1 + f_e)/(1 + r)]^i \cdot E_u \cdot P_e \qquad \text{(Eq. 1.a)}$$

where: $FC = f(E_u)$ for FC.

Substituting $f(E_u)$ for FC,

$$LCC = f(E_u) + \sum_{i=1}^{N} [(1 + f_e)/(1 + r)]^i \cdot E_u \cdot P_e \qquad \text{(Eq. 1.b)}$$

Finally the derivative of each side with respect to E_u is taken in Equation 1.c.

$$\partial LCC = \partial f(E_u)/ E_u + \partial(\sum_{i=1}^{N}[(1 + f_e)/(1 + r)]^i \cdot E_u \cdot P_e)/\partial E_u \qquad \text{(Eq. 1.c)}$$

LCC = life cycle cost,

FC = first cost,

N = average lifetime of appliance,

f_e = fuel price escalation rate,

r = consumer discount rate,

Eu = average annual energy use of applicance, and

P_e = price of energy.

The minimum of the life cycle cost curve occurs when LCC/ E_u is equal to zero. Therefore, the discount rate is determined by setting the right side of Eq. 1.c equal to zero and solving for the only unknown variable, r.

Method 2

The econometric model, illustrated in Eq. 2, attempts to sort out the relative impact of purchase price (the coefficient β_2) and energy use (represented by the coefficient β_1) on the consumer choice of buying a certain type of appliance.

$$EMS/TMS = \alpha + \beta_1 \text{ (PVFS)} + \beta_2 \text{ } (P_e/P_i) \qquad \text{(Eq. 2)}$$

EMS = the number of efficient models of the aplicance purchased each year,

TMS = the total number of models of appliances purchased each year,

PVFS = present value of fuel savings (an average calculation of the fuel savings resulting from the purchase of the more efficient appliance),

P_e = average price of the efficient models, and

P_i = average price of the inefficient models.

The model uses ratios for the independent variable and one dependent variable so that any strange fluctuation in the market for a given year would affect both the efficient and inefficient. Furthermore, the model is flexible. That is, with additional data, more dependent variables could be included, such as advertising budgets, attribute vectors, and manufacturer reputation. The more complete the data, the more precise one can be in explaining consumer decision-making.

There are some shortcomings to this particular model. First, the approach requires an arbitrary definition of what is an efficient and inefficient approach. Second, there could be a major problem of multicollinearity. According to engineering research, the two independent variables should be negatively correlated in an exponential function (i.e., purchase increasing as energy use goes down).[3,4] If this relationship also exists in the market place, then the research must deal with the problems involved with multicollinearity. However, it is not at all clear how energy efficiency and purchase price are related.

Refrigerator Analysis

Preliminary analysis indicates that the consumer is not provided with adequate information to make life cycle cost decisions. As this section will reveal, prices and operating costs of refrigerators are only slightly related if at all. In order to postulate that consumers consciously trade off first costs and operating costs (quantitatively represented by a discount rate), we must first demonstrate that consumers are aware of each set of costs and that their choices represent a consistent preference. Ideally, the consumer decision algorithm will capture the dynamics of appliance purchase decisions and the value or lack of value placed on future energy costs with discount rate that changes over time.

The analysis of regrigertor sales was the logical precedent to an empirical testing of the methods described in the preceding section. Engineering-economic curves of the price versus operating cost always exhibit the trade-off in a negative relationship.[3,4] Thus, the objective of the refrigerator analysis was to test the theoretical relationship, which is the foundation of the methods devised to improve the ORNL consumer decision algorithms.

Refrigerators were selected because adequate data were available and because they represent a major energy end use with little variation in consumption attributable to usage. In addition, consumers generally select their own refrigerator as opposed to buying it "built in" to the house. Finally, main sources of data on refrigerators[5,6] were relatively complete and reliable. Specifically, lists of the retail prices, energy use and models available in the years 1975 and 1977 were used. The statistical analysis included bivariate and multiple regression analysis of purchase price plotted against energy use and/or volume of the refrigerators.

Initially the analysis was intended to demonstrate the relationship between purchase price and efficiency. Both variables were normalized for size of the appliance with kWh per month/total refrigerated ft^3 on the x-axis and purchase price/total refrigerated ft^3 on the y-axis. Refrigerators were separated by 4 types (single door manual defrost, top freezer partial defrost, top freezer automatic defrost and side by side automatic defrost) and each year was run as a separate regression (1975 and 1977).

The bivariate regressions of kWh consumption per month versus purchase price should have reflected the strong negative correlation plotted. This was not the case. The regression revealed a low correlation between energy-consumption and purchase price of refrigerators. In fact, in some cases the correlation exhibited the reverse of the expected relationship, a positive correlation. The proportion of the total variation in the dependent variable (purchase price/total refrigerated volume) explained by the independent variable (kWh per month/total refrigerated volume), which is represented statistically by R^2, was so low that little can be said about the relationship between the two variables.

The results indicated that the hypothesized simple trade-off of efficiency and purchase price of refrigerators did not exist in the market place of 1975 and 1977. There are three reasons why the regression might not have shown a strong relationship between price and efficiency. Manufacturers are constantly developing energy consuming and price inflating gadgets to build into refrigerators. Because no consistent source of data exists on the specific features of refrigerators, they are likely to confound a statistical analysis of the market. Second, freezer volume might influence the efficiency of refrigerators more than total volume. Third, refrigerators have economies of scale. That is, by increasing volume by 10%, the kWh usage would increase by a lesser percentage, everything else being equal. Thus, when we normalized energy use and purchase price by dividing them by total refrigerated volume, many other variables could have masked the true relationship.

To test for the influence of freezer volume and economies of scale, various other regressions were run to provide a clearer understanding of the relationship between efficiency and purchase price of refrigerators. Specifically, purchase price was regressed against energy use (normalized by fresh food and freezer volumes), and the three categories of volume (total refrigerated, fresh food and freezer). Thus the following five regressions were run for the 4 types of refrigerators:

1) x: kWh/freezer ft^3
   y: \$/freezer ft^3

2) x: kWh/fresh food ft^3
   y: \$/fresh food ft^3

3) x: total ft^3
   y: \$

4) x: freezer ft^3
   y: \$

5) x: fresh food ft^3
   y: \$

(Note: kWh = kWh consumed per month; \$ = purchase price in current dollars; total, freezer and fresh ft^3 = refrigerated volumes)

The results indicated that volumes are better estimators of price, especially with the best selling types of refrigerators, top-freezer automatics and side-by-side automatics. With some notable exceptions, purchase price was influenced more by freezer volumes than by total and fresh food volumes. However, when the kWh/price regression was normalized by freezer volume (see 1 above), there were no negative correlations. Furthermore, the R^2 of these bivariate regressions were low for all types of refrigerators. It must be concluded that freezer volumes do not influence the regression of efficiency and price, although they do appear to be good predictors of purchase price.

In order to sort out the relative importance of refrigerator volume and energy use on purchase price, the following multiple regression equation was developed:

$$\text{purchase price} = \alpha + \beta_1 \text{ total ft}^3 + \beta_2 \text{ kWh/month} \quad \text{(Eq. 3)}$$

The regression equation supplied interesting results when run with the refrigerator data. For example, the regression equations for top-freezer automatics were estimated to be:

<u>1975</u>: $Y = 97.5 + 32.9X_1 + .0874X_2$

t-ratios: -.77 7.13 .11

$R^2 = 71.6\%$

1977: $Y = 173 + 36.2X_1 + 2.05X_2$

t-ratios: 1.48 7.92 -2.20

$R^2 = 72.0\%$

(Y = first costs; X_1 = total ft^3; X_2 = kWh/month)

The t-ratios (parameter estimates over their standard deviations) indicate which variables are statistically significant. A useful generalization is that a t-ratio with an absolute value of 2 or more indicates a parameter estimate that is significant at the 95% level.[7] It is clear that total ft^3 (X_1) is a highly significant predictor of the purchase price of a refrigerator. The estimate also has the correct sign; as the total volume of a refrigerator goes up so does its price. For the 1975 regression, the energy use parameter estimate is insignificant; however, the 1977 regression reveals a reverse trend. In 1977, the t-ratio of the energy use parameter is significant at a confidence level of 95% and the sign is correct (negative). In other words, as energy use of a refrigerator increases, the purchase price decreases and vice versa. Note also that the R^2 for each regression is similar to the other and that they are relatively high.

Because it was shown earlier that for some classes of refrigerators the two independent variables (volume and energy use) are correlated, problems of multicollinearity must be considered. In this case, a rule of thumb says that intercorrelation of variables is not necessarily a problem unless it is high relative to the overall degree of multiple correlation.[8] Therefore, with the weak relationship between the two independent variables (fresh food volume and energy use), the problem of multicollinearity is discounted.

The observed trend of energy efficiency influencing purchase price of refrigerators is similar to the theoretical engineering literature discussed earlier in the paper. However, there still exists no clear cut function that explains the trade-off between energy use and purchase price. In fact, it is clear that little or no value has been placed by the purchasing consumer on the future operating costs of major appliances. The lack of sophistication of consumer decisions appears to be a result of the poor information available in the market; specifically, purchase prices rarely indicate the energy efficiency of appliances, thus serving to mask the traditional market relationship between quality and price.

PLANNED ACTIVITIES FOR 1980

The primary problem with market analysis of consumer decisions is the lack of data. A new and comprehensive data set collected by DOE from the manufacturers[9] should be made available by the end of 1979. The future of the consumer decision research within the AEPS project will depend partly on the availability and the quality of the manufacturer data. The research will be extended along the same statistical paths outlined in the refrigerator case for other appliances and for more years. Ideally, the relationships between purchase price and operating costs will be defined through the application of the methods outlined in this paper, even if they exhibit extremely high effective discount rates.

At the present, all consumer decision analysis is focused on the improvement of the ORNL residential demand model. Through application of the model to current practice and AEPS scenarios, the impacts of the standards on residential demand in the United States can be estimated. As a major flow in the ORNL model, the consumer decision algorithms could heavily bias the estimated demand in each scenario. Therefore, it will be necessary to develop new algorithms based on the statistical relationships established. The end result should be an improved version of the ORNL model and consequently, increased accuracy in the AEPS demand analysis.

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THE USE OF DOE-2 TO EVALUATE ADVANCED ENERGY CONSERVATION OPTIONS FOR SINGLE-FAMILY RESIDENCES

D. Goldstein, J. Mass, and M. Levine

INTRODUCTION

The DOE-2 building energy analysis model[1,2] has been used as the basis for deriving life-cycle cost curves for conservation measures in houses. Buildings were modeled under various conditions of insulation and glazing, and the difference in energy use between two conservation options was calculated from DOE-2 runs. Life-cycle costing procedures were used to compare the energy cost savings predicted with the estimated cost of the conservation measure.

The cost curves were derived for use by the U.S. Department of Energy (DOE) as the basis for the residential Building Energy Performance Standards. The economics of many 'conventional' conservation measures were evaluated. It was found that the cost-minimizing houses went considerably beyond current practice in most regions of the country, and saved about 40% of current energy use.[3,4]

Further conservation measures involving advanced technologies (e.g., residential air-to-air heat exchangers) produced an additional savings of 40% or more. However, these measures are subject to controversy concerning their feasibility of implementation. Thus the use of further conservation measures beyond those currently in use somwhere in the U.S. were excluded from analysis.

As the standards are updated it will be important to study the use of such "advanced" conservation measures - those which are not currently in common use. Analysis of the effect of advanced measures may also be of great interest to builders who want to go beyond the standards and approach minimum life-cycle costs more closely, and to those who wish to find some large energy-saver to trade off against a desired energy-wasting feature (e.g., north-facing view windows or 12-foot ceilings).

ACCOMPLISHMENTS DURING 1979

Preliminary analysis has been undertaken on two of the many possible (and potentially cost-effective) advanced technologies for houses. At present, the most encouraging such technology appears to be the reduction in infiltration or accidental air leakage into the house combined with the provision of forced ventilation through a heat exchanger. This technology is most effective in the cold regions. For example, in Minneapolis, Minn., the low infiltration/heat recuperator measure cuts heating loads in half, and saves over $2500 in life cycle fuel bills, at a cost of about $500. In a warmer area, such as Fresno, Ca., the savings are a small fraction of total heating energy, and a much smaller absolute amount of energy. Costs and benefits for a gas-heated house are approximately equal for Fresno.

To analyze this measure, changes were made in the DOE-2 program to allow the calculation of hourly infiltration loads using a Coblentz-Achenbach formula.[5] Formulas appropriate for present "medium" infiltration levels and projected tighter houses were devised and inserted into DOE-2 formulas.

Passive solar techniques are another possible "advanced" technology which can reduce energy use. The effectiveness of passive techniques in saving energy has been established in many demonstration houses. However, their effectiveness in lowering design energy budgets (which are calculated under tightly prescribed conditions of behavior) must be tested for the application of a performance standard.

Passive solar houses depend heavily for their performance on the ability of the structure of the house to store solar heat collected during the day until a period (night or subsequent day) when heating loads would occur. This heat storage is modeled in DOE-2 using "weighting factors", which were derived for a "typical" room of three different weight ranges. The use of weighting factor techniques will not lead to any serious errors in the analysis, but the present procedure of representing all possible rooms by only 3 sets of weighting factors may lead to problems.

We have analyzed the effectiveness of increasing south-facing "direct gain" windows in houses in a wide range of climates, using both the present DOE-2 weighting factors and a new set of weighting factors derived by Consultants Computation Bureaus[7] for specific geometry and construction of our prototype house. We have found surprisingly small differences between the results using the different sets of weighting factors. Heating energy savings from passive solar appear to range from 15% in the colder regions to over 70% in the milder regions.

PLANNED ACTIVITIES FOR 1980

Further research on the two advanced technologies already described is necessary to document the expected energy savings and cost effectiveness estimates. Better analysis of latent heat in the study of heat recuperators and of the sizing of the heat exchanger and its fan is needed.

Passive solar analysis will center on the study of heat storage, and the extent to which this can be modeled using the weighting factors. The study will involve the comparison of DOE-2 results with those of other programs and technologies.

In both cases, we hope to study the effect of ventilation assumptions on the savings potential for cooling loads. Present analysis indicate that passive solar buildings begin to show larger cooling loads as south-facing window area increases (even with extensive shading) and that heat exchangers save very little cooling energy in most climates. Both of these effects may be artifacts of the ventilation algorithm used; we expect to explore this possibility.

Other advanced technologies in which DOE has interest include underground buildings, advanced climate-control systems, and improved window systems. The ability to model these on DOE-2 may depend on the availability of sufficient data to specify the performance of the technology as a function of the relevant variables (e.g., part-load fraction, temperatures or temperature histories, etc.).

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APPLICATION OF THE ORNL RESIDENTIAL ENERGY DEMAND MODEL TO THE EVALUATION OF RESIDENTIAL ENERGY PERFORMANCE STANDARDS

J. McMahon and M. Levine

INTRODUCTION

The Oak Ridge National Laboratory (ORNL) Residential Energy Demand Model (REDM) was developed to simulate energy use in the residential sector from 1970 to 2000.[1,2] This model can be used as a tool to evaluate the effects of residential energy performance standards and other possible government policies. Application of this model can yield a comparison of a base case (without standards) with the case including implementation of standards. Particular attention will be paid to effects on fuel consumption, fuel costs, and capital costs for new equipment.

The major capabilities of the REDM are that it:

- shows energy demand over time, disaggregated according to fuel type, housing type, and end use;
- considers changes due to economic factors affecting market shares, usage, and technological improvements of appliances;
- distinguishes new equipment energy performance from average energy performance of the total stock;
- calculates economic trade offs between operating cost and capital cost; and
- includes retrofit of existing houses when economically justified.

Effective analysis of proposed standards requires that 1) the REDM simulates energy use reasonably well; and 2) the input data must be the best available, with regard to both accuracy and level of detail. The range of values for inputs should be specified, and the sensitivity of results to various input assumptions must be tested to define the range of values for key effects.

ACCOMPLISHMENTS DURING 1979

The model has been obtained from ORNL and installed in an LBL research computer. The input data have similarly been imported and used to verify the integrity of the transferred model.

The results of applying the ORNL model to buildings energy performance standards (BEPS) have been duplicated. Sensitivity of the results to key input economic assumptions are being tested, in order to gain further familiarity with the detailed inner workings of this model.

The methodology programmed into the model (and described in existing documentation[1,2,3]) has been examined in detail. Several aspects of the model are receiving close scrutiny with the intent of replacing some parts with improved formulations based on more recent empirical data.

The new approaches to be implemented are described separately. Of particular interest are: modeling of consumer decision making, and consideration of electricity peak load (not previously included).

A few complete sets of input have been prepared at different geographic levels (national, federal region, and utility service area). The overall effects of appliance standards will be analyzed at the national level, but modeling of peak load requires attention to a utility service area. Inputs include stocks of occupied housing, new construction, equipment ownership (market shares), new equipment installation, annual equipment fuel use, equipment prices, fuel prices, income, new equipment standards, thermal performance standards for new buildings and for retrofit programs, and characteristics of new technologies.

PLANNED ACTIVITIES FOR 1980

The ORNL model will be modified to include the most current formulation for consumer decision-making, retirement rates of appliances, and electricity peak loads. Other possible improvements include explicit treatment of solar as a fuel type, and provision for down-sizing of appliances as operating costs increase.

The Residential Energy Demand Model will be applied to proposed national design standards for residential appliances. Comparing the results of two runs of the model (one a base case (without standards), the other the standards case) will provide detailed information about the effects of standards. Since the two runs share the same economic and demographic assumptions, the difference in key outputs can be attributed to implementation of the standards.

The outputs of particular concern will be fuel use (use by fuel type, end-use function, and housing type), annual fuel costs (total cost and cost by fuel type), annual expenditures for new equipment and for thermal integrity improvements, and total fuel use and expenditures over the period 1980 to 2000.

The net present value - that is, the discounted value over the period of time considered - of fuel costs, equipment costs, and structure improvement costs will be calculated by the model for the two cases. The difference in net present value between the two case yields both fuel costs saved due to standards, and change in equipment costs due to standards. The net economic benefit to society (excluding the cost of government programs) is the difference between fuel costs saved and change in equipment costs.

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ENERGY INFORMATION VALIDATION

M. Horovitz

PROJECT ACTIVITY

The Energy Information Administration (EIA) of the U.S. Department of Energy (DOE) is responsible for conducting a comprehensive energy data and information program. EIA operates over one hundred information systems, numerous models and forecasting procedures, and is required to assess the validity of these systems and the information generated through their use. Such validation studies require investigation of the accuracy, utility and efficiency of the information system.

An Energy Information Validation Project was started at LBL in January 1978 and grew rapidly in scope and size. Validation studies of five energy information systems were carried out; the broader objectives of the program were to use the experience gained during these first five studies to create methods for efficient validation of the many information systems for which EIA is responsible.

Interim reports[1-5] on validation studies of five information systems were delivered to EIA in December 1978. In January 1979, EIA decided to terminate the LBL Energy Information Validation Project as quickly as possible. The project was closed down by the end of February 1979. During February 1979 it was decided that a small core of the project staff should carry out a review of lessons learned during the previous year's work and document certain findings and knowledge gained. This review was completed in July 1979 with production of four additional reports.[6-9] A study of the history of oil and gas reserve estimation was also conducted, through a subcontract in FY 1979. The draft report[10] on this study was completed at the close of FY 1979. A report on the techniques developed at LBL for validation of the information systems is being prepared for completion during FY 1980; this constitutes the final item to be produced by the project.

A related but separate study was begun in June 1979 to assess the validity of DOE's energy demand forecasting methods. EIA currently uses the ORNL Engineering Economic Model of Residential Energy Use (Hirst-Carney model) developed at Oak Ridge National Laboratory, to forecast energy demand in the residential sector, to the year 2000. Previously, EIA had carried out this task by using the RDFOR model which was part of the Project Independence Evaluation System (PIES).

A preliminary review of the RDFOR model was carried out at LBL and U.C. Berkeley during the summer of 1979 and drafts of three reports[11-13] were produced and submitted for review at the end of FY 1979. A report on preliminary studies of the Hirst-Carney model is planned for completion during the first half of FY 1980. During FY 1980, this study will be transferred from LBL to the U.C. Berkeley Statistics Department, where it is scheduled for completion during FY 1981.

This first LBL energy information validation project carried out pioneering studies covering a broad range of topics related to the validity of information about energy and created an approach to validation of information systems. Three out of five information systems and one of the models studied were found to have defects which seriously impaired the credibility of information generated through use of these systems.

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EVALUATION OF BUILDING ENERGY PERFORMANCE STANDARDS FOR RESIDENTIAL BUILDINGS

M. Levine, D. Goldstein, M. Lokmanhekim, J. Mass, and A. Rosenfeld

INTRODUCTION

In August of 1976, in response to the need for encouraging greater conservation of depletable energy resources in new buildings, Congress passed the Energy Conservation Standards for New Buildings Act of 1976. The Act mandated the development, promulgation, implementation, and administration of energy performance standards for all new buildings constructed in the United States after 1981.

The importance of the Building Energy Performance Standards (BEPS) program in the residential sector is underscored by results showing that setting the residential standard at the minimum in life-cycle costs using only traditional energy conservation measures can:

- reduce energy use for space conditioning by about 30% - 40% from current building practice (or 60% - 70% from an average house built before the OPEC oil embargo of 1973)

- produce a net savings in life-cycle costs of more than $1,000 to an average new homeowner.

Lawrence Berkeley Laboratory (LBL) was assigned primary responsibility for the support of the U.S. Department of Energy's (DOE's) development of the energy performance standards for single-family residential buildings in December, 1978. During Fiscal Year 1979, LBl completed the following tasks in support of the standards development:

1. Development of prototype designs for single-family residential buildings;

2. Description of conservation measures and building operating conditions for residential dwellings;

3. Building energy simulations using a state-of-the-art energy analysis computer program (DOE-2) of four buildings in ten locations with approximately twelve combinations of energy conservation measures for each building;

4. Development and application of a computer program to evaluate the life-cycle costs of the conservation measures in the residential buildings;

5. Analysis of the sensitivity of the life-cycle cost curves to variations or uncertainties in key economic parameters and building and climate characteristics;

6. Preparation of a series of memos and issued papers on the key policy issues resulting from the analysis of Residential Building Energy Performance Standards (BEPS); and

7. Active participation with DOE in the preparation of the Notice of Proposed Rulemaking for the BEPS.[1]

The LBL research effort during Fiscal Year 1980 will focus on: (1) key issues that need to be resolved for the final rulemaking; (2) planning of a research effort to increase the energy conservation potential in residential buildings, in support of an update of the standards anticipated in 1985; (3) initiation of selected research tasks treating advanced energy conservation technologies (discussed in an article in this volume by D. B. Goldstein, J. Mass, and M. D. Levine); (4) support for DOE in its efforts on commercial buildings and mobile homes; and (5) participation in DOE's public information program on BEPS.

METHOD OF APPROACH

The approach followed in the analysis of residential space conditioning energy performance standards involves the following steps:

1. Development or residential prototypes,

2. Selection of conservation measures to be evaluated,

3. Description of standard building operating conditions,

4. Development of economic data, projections, and assumptions,

5. Computer simulation of building energy requirements in different climatic regions,

6. Analysis of life-cycle costs of energy conservation measures,

7. Sensitivity analyses on building characteristics, operating conditions, conservation measures, and economic parameters, and

8. Analysis of impacts of alternative energy budget levels, in which the alternative budget levels are based on steps 1 through 7.

The basis of the analysis method is the use of life-cycle costing. The objective of achieving a minimum in life-cycle costs is a reasonable basis for establishing energy conservation policy because it provides a rational framework for trading off scarce energy resources and other resources (e.g., labor and capital) in achieving a particular goal (in this case, space conditioning in residential buildings).[2] The use of an economic approach to energy conservation--and the increasing public awareness of how economics can help resolve issues--can be greatly enhanced by a government decision to use life-cycle costing as one of the major elements of its energy conservation policy.

Specifics of Approach and Assumptions

The most important specific elements of the approach to evaluating the life-cycle cost of energy conservation measures for single-family residential buildings are summarized below. More detailed information on the assumptions used in the analysis is found in Ref. 3. More detailed information about the results of sensitivity analyses is found in Chapter 4 and appendices A and I of Ref. 4.

Residential Prototypes

- Four designs selected, following Hastings:[5] single story ranch, two story, townhouse, and split level house.
- Window area taken to be 15% of floor area for all designs.
- Windows equally distributed on all four sides of house (two sides for townhouse).
- Sensitivities of prototypes performed:

  --window area
  --window orientation
  --house size and orientation
  --aspect ratio of house
  --thermal mass of house
  --conservation measures (see below)
  --building operating conditions (see below)

Conservation Measures

- Windows: up to triple glazing (or double glazing plus storm window).
- Exterior wall: up to R-25 (using 2" x 6" studs plus insulating sheathing).
- Ceiling: up to R-38 insulation.
- Excludes: exterior wall with double studs (two 2 x 4 or 2 x 8 studs with insulation); ceiling insulation greater than R-38; infiltration reduction (with or without heat recuperator); any conservation measure requiring a change in behavior; other advanced energy conservation technologies.

Building Operating Conditions

- Thermostat set points: 70°F for heating; 78° for cooling; no night setback.
- Average air infiltration rate: 0.6 air changes per hour.
- Average internal loads: 50,000 Btu/day, Highest in early morning (cooking, occupants, lighting) and evenings (cooking, lighting, occupants, TV).
- Natural ventilation: windows open when indoor temperature greater than 78°F and outdoor temperature low enough to cool house to 78° in less than one hour. Non-opening windows considered as a sensitivity case.

Economic Data, Projections, and Assumptions

- E.I.A. average energy price projections (Series B)

  --Gas prices escalate at 2.8% per year above inflation,
  --Electricity prices escalate at 1.5% per year above inflation.

- Installed cost of energy conservation measures from N.A.H.B.
- Discount rate chosen to equal cost of borrowed capital for a new house (3% above inflation).
- Possible future changes in assumptions:

  --marginal energy prices
  --updated conservation costs
  --regional prices

Building Energy Simulations

- Use of DOE-2 computer program, checked against TWOZONE and BLAST.
- Change in infiltration and ventilation algorithms.
- Run for 4 prototypes, about 12 groups of conservation measures per prototype, two ventilation algorithms and 10 cities.

RESULTS

Gas Heated Houses

Table 1 contains the detailed results obtained by minimizing the life-cycle costs of energy conservation investment and a discounted stream of payments for fuel over the lifetime of the house mortgage, for a house with natural gas heating (assuming a system efficiency of 70 percent) and electric cooling. The first column lists the climatic regions. The second column presents the representative city for which the thermal analysis of the residence was performed. Columns 3 and 4 show the long-term average heating and cooling degree days for each of the cities. The heating degree days are presented with a base of 65°F and, in parentheses, a base of 53°F. The cooling degree days are presented with a base of 65°F and, in parentheses, a base of 68°F. (The 53°F base for heating and 68°F for cooling are included because space heating and cooling loads for a well-insulated house are expected to be more nearly linear with degree days calculated on this basis than for the traditional base of 65°F.)

Table 1. Results of the life-cycle cost analysis of energy conservation measures for single story houses heated by natural gas and cooled by electricity.

1	2	3	4	5			6	7	8	
				Insulation Levels of Nominal Case (R-Value)					Natural Gas Energy Budget	
Climate Region	Representative City	Heating Degree-Days[a]	Cooling Degree-Days[a]	Ceiling	Wall	Floor	Glazing of Nominal Case	Conservation Investment, $1978	Primary Energy, MBtu/sq. ft./yr	Building Boundary, MBtu/sq. ft./yr
1	Minneapolis	8310 (5260)	530 (370)	38	25	--	3	$1,160	66.1	54.5
2	Chicago	6130 (3540)	930 (620)	38	19	--	3	$ 900	42.9	35.0
3	Portland	4790 (1840)	300 (150)	38	19	19	3	$1,050	30.9	25.9
3	Washington, D.C.	4210 (1980)	1420 (1010)	38	19	--	3	$ 900	33.7	22.4
4	Atlanta	3100 (1230)	1590 (1130)	38	19	11	2	$ 900	28.2	18.3
4	Fresno	2650 (770)	1670 (1220)	38	19	--	2	$ 850	31.9	16.1
5	Burbank	1820 (170)[b]	620 (310)[b]	19	11	--	2	$ 380	15.7	7.2
6	Phoenix[c]	1550 (320)	3510 (2960)	38	19	--	3	$1,280	35.8	12.0
6	Houston	1430 (360)	2890 (2240)	30	11	--	2	$ 520	34.4	15.1
7	Ft. Worth[c]	2830 (810)	2590 (2030)	38	19	--	3	$1,280	32.3	15.2

[a]Heating and cooling degree-days base 65°F presented; heating degree-days base 53°F in parentheses; cooling degree-days base 68°F in parentheses.

[b]Degree-days for Los Angeles reported.

[c]Under the EIA Medium Price Projections (December 17, 1978) both Phoenix and Ft. Worth would have used double glazing at a conservation investment of $850. Primary energy use was 40.1 and 36.8 MBtu/sq. ft./yr for Phoenix and Ft. Worth, respectively.

Column 5 presents the insulation levels and column 6 the number of glazings in the prototype house which minimized life-cycle costs.* These insulation levels would bring most houses into compliance with the energy budgets. Of course, many other configurations would also comply. Triple glazing is used in climates as cold as Washington, D.C., and in areas with very large cooling load, and double glazing is used in all other climates modeled. Typical insulation levels for all but the extreme climates (coldest or mildest) are R-38 ceiling and R-19 walls. Column 7 contains the estimated increase in investment (for an 1176 square foot house) for the conservation measures compared with current investment in conservation in the different climates. (The estimates of current conservation investment are based on a NAHB survey, results of which are contained in Table 2.[6]) Column 8 contains the energy budget at the life-cycle cost minimum, which we have previously defined as the Design Energy Budget of a house. We have expressed these budgets in terms of primary energy use and use at the building boundary.

There are numerous ways that the Design Energy Budgets can be met in the different climates. Table 3, taken from Refs. 1 and 7, illustrates two or three alternative ways of achieving the Design Energy Budgets in three climates.

Electric Resistance Heated Houses

Table 4 summarizes the life-cycle costing results for electric resistance heating. Columns 5 and 6 show the standard insulation and glazing levels that will meet the designed energy budgets of the nominal case: R-38 ceiling and triple glazing insulation is used in all climates except the most mild (Burbank); R-25 wall insulation is used in all climates as cold as or colder than Washington, D. C. and R-19 wall insulation in all other climates. Thus, in all climates except region 1 (Minneapolis), the standard conservation measures for houses using electric resistance heating are stricter than those for natural gas-heated houses. The investment in energy conservation for the electric resistance heated houses reflects the use of tighter measures for all climates except Minneapolis. The increased investment in energy conservation (beyond estimated 1975 current practice) is between $1,160 and $1,433 for the 1176-ft^2 wood frame prototype house.

Houses Heated and Cooled with Heat Pumps

Table 5 summarized the life-cycle costing results for heating and cooling with an electric heat pump. Column 8 in Table 5 presents the seasonal coefficients of performance (COP) of heat pumps in the heating mode in ten climates. These COPs are based on the simulation of available efficient heat pumps in ten climates by the Oak Ridge National Laboratory.[8] The COP for a heat pump is reported as 10% lower than can presently be achieved by commercial models to account for heat losses in the ductwork associated with the heat pump.

Comparison of the Design Energy Budgets for the electric heat pump (column 9 in Table 5) with electric resistance heating (column 8 in Table 4) reveals that the heat pump budget is lower than the electric resistance budget in almost all cases. The heat pump budget is significantly lower in cool and cold climates. An economic evaluation of electric heating using heat pumps and using resistance heating indicates that the heat pump system has lower life-cycle costs than resistance heating in cool and cold climates, in spite of the higher first costs of the heat pump.[9]

Table 6 illustrates alternative ways of meeting the Design Energy Budgets that were obtained for homes heated and cooled by heat pumps in three climates.[1,7]

Comparison with Current and Past Energy Conservation Construction Practice

Figure 1 presents a comparison of fuel requirements for space heating using natural gas for a large number of different cases. The upper curve, labeled "U.S. stock, Dole 1970," is the best available estimate of the fuel requirements for space heating the 1970 stock of houses in the United States.[10] The fourth curve from the top labeled "Current Practice (DOE-2)," is our best estimate of the current construction practice in houses built after the 1973 oil embargo. This

Table 2. Standard energy conservation measures for residential houses constructed in 1975, based on data from the 1977 NAHB survey.

City	Standard Practice, 1975 C	W	F	Gl[a]
Minneapolis	22	11	--	2
Chicago	19	11	--	2
Portland	19	11	7	2
Washington, D.C.	19	11	--	2
Atlanta	19	11	7	1
Fresno	19	11	--	1
Burbank	19	11	--	1
Phoenix	19	11	--	1
Houston	19	11	--	1
Ft. Worth	19	11	--	1

[a] C = ceiling R-value; W = wall R-value; F = floor R-value (if applicable); Gl = number of glazings for all windows.

*For regions in which a crawl space is the common form of basement, the floor insulation levels are noted in Table 1. For unheated full basements, the assumption is made that heat losses and gains balance. Slab on grade and basement construction is assumed to have adequate perimeter insulation, as described in Ref. 1.

Table 3. Illustrative ways of meeting the design energy budgets for single family residences in three locations: gas heated homes.

Location	Sets of Options
Chicago, IL	1. Average window area and distribution;[a] triple glazing;[b] R-38 ceiling and R-19 wall insulation.
	2. Windows redistributed so that south facing window area increased by 75% and east, west, and north facing window area decreased by 25%; double glazing; R-38 ceiling and R-9 wall insulation.
	3. Active solar domestic water heating system;[d] double glazing; R-38 ceiling and R-11 wall insulation.
Atlanta, GA	1. Average window area and distribution;[a] double glazing; R-38 ceiling, R-19 wall, and R-11 floor[c] insulation.
	2. Windows redistributed so that south facing window area increased by 75% and east, west and north facing window area decreased by 25%; double glazing; R-30 ceiling, R-11 wall and R-11 floor insulation.
	3. Active solar domestic water heating system;[d] double glazing; R-19 ceiling, R-11 wall and R-7 floor insulation.
Houston, TX	1. Average window area and distribution;[a] double glazing; R-30 ceiling and R-11 wall insulation.
	2. Active solar domestic water heating;[d] R-19 ceiling and R-11 wall insulataon.
	3. Other alternatives, such as passive solar design and redistribution of windows, not evaluated for Houston.

[a] The average window area is 15% of total floor area. The windows are distributed equally among the exterior walls.

[b] Double glazing plus storm windows can substitute for triple glazing with little change in the Design Energy Consumption of the house.

[c] Floor insulation is noted in Atlanta, Georgia, and all other areas where crawl-space basements are used.

[d] The active solar domestic water heating is assumed to be sized at 60% of the water heating load in a 1500 square foot house for the purpose of this illustration.

Table 4. Results of the life-cycle cost analysis of energy conservation measures for single story houses heated and cooled by electric heating (other than heat pumps).

1	2	3	4	5			6	7	8	
				Insulation Levels of Nominal Case (R-Value)					Electrical Energy Budget	
Climate Region	Representative City	Heating Degree-Days[a]	Cooling Degree-Days[a]	Ceiling	Wall	Floor	Glazing of Nominal Case	Conservation Investment, $1978	Primary Energy, MBtu/sq. ft./yr	Building Boundary, MBtu/sq. ft./yr
1	Minneapolis	8310 (5260)	530 (370)	38	25	--	3	$1,160	132.2	38.9
2	Chicago	6130 (3540)	930 (620)	38	25	--	3	$1,190	80.0	23.5
3	Portland	4790 (1840)	300 (1010)	38	25	19	3	$1,350	58.5	17.2
3	Washington, D.C.	4210 (1980)	1420 (1010)	38	25	--	3	$1,190	53.7	15.8
4	Atlanta[c]	3100 (1230)	1590 (1130)	38	19	19	3	$1,433	39.6	11.6
4	Fresno	2650 (770)	1670 (1220)	38	19	--	3	$1,280	38.6	11.4
5	Burbank	1820 (170)[b]	620 (310)[b]	30	19	--	2	$ 760	15.1	4.4
6	Phoenix	1550 (320)	3510 (2960)	38	19	--	3	$1,280	38.5	11.3
6	Houston	1430 (360)	2890 (2240)	38	19	--	3	$1,280	33.6	9.9
7	Ft. Worth	2830 (810)	2590 (2030)	38	19	--	3	$1,280	43.0	12.6

[a]Heating and cooling degree-days base 65°F presented; heating degree-days base 53°F in parentheses; cooling degree-days base 68°F in parentheses.

[b]Degree-days for Los Angeles reported.

[c]Under the EIA Medium Price Projections (December 17, 1978) Atlanta used R-11 floor insulation for a conservation investment cost of $1,330 and a primary energy budget of 40.7 MBtu/sq. ft./yr.

Table 5. Results of the life-cycle cost analysis of energy conservation measures for single story houses heated and cooled by electric heat pumps.

1	2	3	4	5			6	7	8	9	
				Insulation Levels of Nominal Case (R-Value)						Electrical Energy Budget	
Climate Region	Representative City	Heating Degree-Days[a]	Cooling Degree-Days[a]	Ceiling	Wall	Floor	Glazing of Nominal Case	Conservation Investment, $1978	Heat Pump Seasonal COP	Primary Energy, MBtu/sq. ft./yr	Building Boundary, MBtu/sq. ft./yr
1	Minneapolis	8310 (5260)	530 (370)	38	25	--	3	$1,160	1.38	98.3	28.9
2	Chicago	6130 (3540)	930 (620)	38	25	--	3	$1,190	1.52	54.6	16.1
3	Portland	4790 (1840)	300 (1010)	38	19	19	3	$1,050	1.87	34.9	10.3
3	Washington, D.C.	4210 (1980)	1420 (1010)	38	19	--	3	$ 900	1.79	37.7	11.1
4	Atlanta	3100 (1230)	1590 (1130)	38	19	11	3	$1,330	1.82	27.0	7.9
4	Fresno	2650 (770)	1670 (1220)	38	19	--	3	$1,280	2.02	28.6	8.4
5	Burbank	1820 (170)[b]	620 (310)[b]	30	11	--	2	$ 520	2.02	4.6	4.3
6	Phoenix	1550 (320)	3510 (2960)	38	19	--	3	$1,280	1.92	36.0	10.6
6	Houston	1430 (360)	2890 (2240)	38	19	--	3	$1,280	1.83	28.5	8.4
7	Ft. Worth	2830 (810)	2590 (2030)	38	19	--	3	$1,280	1.83	33.9	10.0

[a]Heating and cooling degree-days base 65°F presented; heating degree-days base 53°F in parentheses; cooling degree-days base 68°F in parentheses.
[b]Degree-days for Los Angeles reported.

Table 6. Illustrative ways of meeting the design energy budgets for single family residences in three locations: electric heated homes.

Location	Sets of Options
Chicago, IL	1. Average window area and distribution;[a] triple glazing;[b] R-38 ceiling and R-25 wall insulation; heating supplied by a heat pump.
	2. Windows redistributed so that south facing window area increased by 36% and east, west, and north facing window area decreased by 12%; triple glazing; R-38 ceiling and R-19 wall insulation; heating supplied by heat pump.
	3. Active solar domestic water heating system;[d] double glazing; R-38 ceiling and R-25 wall insulation; heating supplied by electric resistance.
Atlanta, GA	1. Average window area and distribution;[a] triple glazing;[b] R-38 ceiling, R-19 wall, and R-11 floor[c] insulation; heating supplied by heat pump.
	2. Windows redistributed so that south facing window area increased by 80% and east, west, and north facing window area decreased by 27%; double glazing; R-38 ceiling, R-19 wall, and R-11 floor[c] insulation; heating supplied by heat pump.
	3. Active solar domestic water heating system;[d] double glazing; R-30 ceiling, R-19 wall, and R-11 floor[c] insulation; heating supplied by electric resistance.
Houston, TX	1. Average window area and distribution;[a] triple glazing;[b] R-38 ceiling and R-19 wall insulation; heating supplied by heat pump.
	2. Active solar domestic water heating system;[d] R-19 ceiling and R-11 wall insulation.

[a] The average window area is 15% of total floor area. The windows are distributed equally among the exterior walls.

[b] Double glazing plus storm windows can substitute for triple glazing with little change in the Design Energy Consumption of the house.

[c] Floor insulation is noted in Atlanta, Georgia, and all other areas where crawl-space basements are used.

[d] The active solar domestic water heating is assumed to be sized at 60% of the water heating load in a 1500 square foot house for the purpose of this illustration.

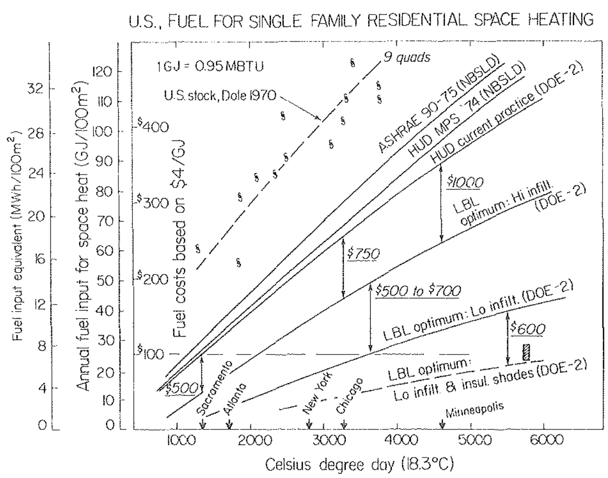

Fig. 1. Fuel for single family residential space heating (U.S.). (XBL 795-1396)

curve is based on survey data for the years 1975 and 1977 and on results of DOE-2[11] computer calculations performed at LBL.[4] The fifth curve from the top, labeled "LBL optimum medium infiltration," contains the results of life-cycle costing analysis for gas heated houses. The sixth curve, labeled "LBL optimum: low infiltration (DOE-2)," illustrates the energy requirements for a house with infiltration levels reduced from 0.6 to 0.2 air changes per hour. For this case the assumption is made that mechanical ventilation through a heat recuperator restores the outside air exchange rate to 0.6 air changes per hour.

CONCLUSIONS

Figure 1 indicates that very large energy savings can be accomplished by requiring all new houses to use all commonly available cost effective energy conservation measures. BEPS can result in a substantial improvement in the thermal integrity of new houses in the United States and at the same time save the consumer money. The magnitude of the energy savings is sufficiently great as to go a long way toward reducing growth in energy demand in the Nation. (About 35% of energy in the Nation is consumed in buildings with about half of this amount consumed in residential buildings.)

If BEPS is set at the minimum in the life-cycle cost curves (as proposed in DOE's NOPR)[1] and if all new residential buildings meet BEPS then:

- a reduction of 30% to 40% in the average energy use for residential space conditioning (from current building practice) is accomplished. This is a reduction of 60% to 70% from the energy use of an average existing house, built before the OPEC oil embargo in 1973.
- simple payback on conservation investment occurs in 1 to 4 years for electric heat and 3 to 10 years for gas heat;
- an increased investment of $0.50 to $1.00 per square foot for a new house is required (i.e., an increased initial investment of 1.5% to 3%); and
- the new home owner achieves a net savings of $800 to $1500 over the life of the house mortgage, in addition to a higher selling price of the house.

If the list of conservation measures is expanded to include just one conservation technology (reduced air infiltration combined with mechanical venting through a heat exchanger), then

- a reduction of 50% to 60% in average energy use for residential space conditioning (from current building practice) can be accomplished. This is a reduction of 75% to 85% from the energy use of an average existing house;
- this requires an increased initial investment of $0.75 to $1.50 per square foot.
- the net savings is $1500 to $4000 to the new house owner, in addition to a higher selling price of the house.

PLANNED ACTIVITIES FOR 1980

The BEPS program at LBL has been expanded for Fiscal Year 1980. The following activities are either underway or planned:

1. Analysis in support of Final Rulemaking:
   - development of new prototype,
   - detailed assessment of the economics and thermal performance of residential heating and cooling equipment (including heat pumps) and water heaters,
   - application of life-cycle costing to heating and cooling equipment, water heaters, and the building envelope,
   - continued analysis of the economics and energy performance of exterior masonry walls,
   - final computer curves of conservation measures for four prototypes in 32 locations,
   - sensitivity studies of the effects of changing window size and orientation, conservation measures, internal thermal mass, and other building characteristics,
   - continuing analysis of the impact of uncertainty in key economic parameters on the development of the standards (see paper by P. P. Craig, M. D. Levine, and J. Mass on this subject in Energy, in press),

- study of other key issues related to the promulgation and implementation of standards:

  --computer program comparison and validation,
  --credits for the use of renewable resources,
  --assessment of how many energy budgets are needed,
  --continued analysis of how energy budgets for different fuels are compared.

2. Planning of energy conservation research to support an update of the standards in 1985.

3. Research on selected advanced energy conservation measures, including infiltration with mechanical ventilation through a heat exchanger, direct gain passive solar, and advanced concepts for energy conservation in windows.

4. Support for DOE in its analysis of commercial buildings and mobile homes.

5. Participation in DOE's public information program on the Building Energy Performance Standards.

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ENERGY EFFICIENCY STANDARDS FOR RESIDENTIAL APPLIANCES INCLUDING HEATING AND COOLING EQUIPMENT

M. Levine, S. French, J. McMahon, R. Pollack, and I. Turiel

INTRODUCTION

The National Energy Conservation Policy Act (NECPA) mandates that Appliance Energy Efficiency Standards be prescribed by October of 1980. The law requires that the standards be designed to achieve the "maximum improvement in energy efficiency" that is "technologically feasible and economically justified." Determination of the economic justification must be based on: the savings in operating costs over the average life of the appliance compared to the increase in the initial purchase price or maintenance costs likely to result from the imposition of the standard; the economic impact of the standard on the manufacturers and the consumers of the appliances; the total projected energy savings likely to result directly from the imposition of the standards; and other relevant factors. Clearly, it will be necessary to systematically develop appliance standards that achieve minimum life cycle costs and to evaluate the total impact on residential energy demand resulting from the implementation of the standards.

The Appliance Efficiency Performance Standards (AEPS) program at LBL will perform analysis of residential energy demand in support of the appliance standards as outlined in NECPA. One major tool of the demand analysis will be the Oak Ridge National Laboratory (ORNL) Engineering-Economic Model of Residential Energy Use, which provides detail on the energy use of eight major end uses by four fuel types in the residential sector. A second important tool is the DOE-2 Model, which analyzes the energy use of buildings. The DOE-2 Model needs to be extended to simulate the performance of residential heating and cooling equipment for it to be used in the evaluation of energy efficiency standards for this equipment. Two additional analytic tools are under development at LBL in support of the appliance efficiency standards: (1) a model to assess the bases of consumer decision making in the purchase of appliances, with particular emphasis on the factors influencing the efficiency of consumer products purchased, and (2) a model to assess the effects of alternative standards for residential energy use on the peak loads of electric utilities.

PROGRAM OVERVIEW

The purpose of the Appliance Energy Performance Standards (AEPS) program at LBL is to provide assistance to the U.S. Department of Energy (DOE) in the formulation of energy efficiency standards for appliances. This purpose will be achieved by establishing base cases for energy demand with and without appliance efficiency standards (with appropriate sensitivity analyses), by evaluating the efficiencies of heating and cooling equipment in different climates and in houses with differing levels of conservation (by performing hourly computer simulations over the course of a typical year), by assessing the effects of appliance efficiency standards on peak loads of utilities, and by assisting DOE in its development of an overall methodology for evaluating alternative energy performance standards.

The specific primary tasks for F.Y. 1980 are:

Task 1: Establish base case projections of appliance energy use using the ORNL residential energy demand model.

Task 2: Perform preliminary assessment of consumer decisionmaking in the purchase of appliances; use results to refine the ORNL base case projections (in Task 1).

Task 3: Analyze the weather sensitivity of heating and cooling systems, using DOE-2 computer program for houses of varying conservation levels.

Task 4: Assess the life-cycle costs of a wide range of energy conservation measures for heating and cooling equipment, using the results of Task 3 and engineering/economic data supplied by DOE.

Task 5: Assess impacts of appliance efficiency standards on utility peak loads, using results of Task 4 and peak load data from selected utility service areas.

Task 6: Assist DOE in developing ranking methodology to assess alternative standards; apply methodology to establish alternative standards.

Original analysis on performance of equipment in different climates and types of houses, specified in Task 4, is limited to heating and cooling systems and does not cover other appliances.

SPECIFIC DETAILS OF APPROACH

Table 1 shows the relationships among the tasks (and subtasks) of the research effort and indicates how the results can be used to support the development of energy performance standards for residential appliances.*

An explanation of the information flows in the project, as designated by the letters A through

*Although the approach can be applied to any appliance, LBL's effort will place greatest emphasis on residential heating and cooling equipment.

Table 1. Overview of LBL Appliance Performance Standards (AEPS) Program.

Task No.	Title	Output Information Flow	Feeds Into Tasks	Program Output
1	Base Case Analysis (no standards)	A*	1-1	
2	Improve ORNL Model (emphasis on consumer decisionmaking)	B	1-1	
		J	1-2	
		M	6	consumer decision-making & energy growth Analysis & policy consideration
3	Extend DOE-2 Model for Residential Heating & Cooling Equipment	C	4	
		D	4-1	
4	Preliminary Life-Cycle Cost Analysis	F	1-1	
		G	4-1	
1-1	Assess Base Case	---	1-2	
5	Peak Load Analysis	E	---	Effects of Standards on Peak Loads
		H	4-1	
4-1	Extended Life-Cycle Cost Analysis	I	1-2	
		K	6	
		K	---	Life Cycle-Cost Curves; Sensitivities
1-2	Assess Standards Case, Reasses Base Case	L	6	
		N	---	Residential Energy Projections with and without Standards; Net Present values; sensitivities
6	Policy Analysis of Alternate Standards	O	---	Economic Impacts of Alternate Energy Performance Standards for Residential Appliances

*Capital letters refer to Information Flows discussed in the text.

O, on Table 1, provides an understanding of how the individual tasks support the establishment of standards. The information flows in Table 1 are as follows:

A: assessment of elements of ORNL model projection in need of improvement,

B: improvements in ORNL model; preliminary consumer decision-making model,

C: derivation of annual heating and cooling energy use from hourly simulations,

D: Sensitivities of annual heating and cooling energy use to weather; building envelope conservation measures; equipment size; equipment performance characteristics,

E: impact of different appliance energy standards on peak load performance of utilities,

F: refined data base for ORNL model (energy use of appliances and cost of efficiency improvements),

G: refined data for complete life-cycle cost analysis,

H:* peak power use by appliances and cost of peak power; oil use (through use of peak power),

I: final data base on costs of energy conservation measures and associated energy savings,

J: final improvements in ORNL model; refinement of consumer decision-making algorithm,

K: final results of life-cycle cost analysis, including sensitivities (see C and D),

L: results of residential energy projections with and without standards; results of net present value analysis,

M: effects of alternative policy approach on consumer decision-making and vice-versa,

N: final results of residential energy use projections and net present benefit (cost) of alternative standards,

O: final results of selected direct economic impacts of alternative formulations of standards (including regional versus national standards) and levels of standards.

FUTURE PLANS

LBL intends to continue its Appliance Energy Performance Standards program after the final rule is issued in F.Y. 1980. In particular, the following four tasks will be pursued:

- determinants of residential peak loads and the impact of federal policies (including energy performance standards) on peak loads,
- elements of consumer decision-making that affect purchase of energy efficient products; policy implications of consumer decision-making,
- improvements and application of residential energy forecasting tools (especially the ORNL model),
- analysis in support of updating the appliance energy performance standards.

*This information will not be available except in very preliminary form during F.Y. 1980.

THE IMPACT OF ENERGY PERFORMANCE STANDARDS ON THE DEMAND FOR PEAK ELECTRICAL ENERGY

M. Levine, J. McMahon, S. French, and R. Pollack

INTRODUCTION

A major issue in the assessment of residential energy performance standards (the subject of two LBL programs--residential building and appliance standards analysis--discussed in this volume) is the effect of standards on the peak loads of electric utilities. The importance of this issue is twofold:

- If the standards reduce the use of peak power more than they reduce base power demand, then they will provide benefit to utilities in reducing the peak to base ratio (and thus reduce the requirement for new generating capacity). This will save the utilities and utility customers money, both because of the reduced growth of generating capacity and because of the reduced demand for peak power (which is generally two to four times as expensive as baseload power).

- To the extent that an appliance consumes peak rather than base electricity, the economics of energy conservation should be evaluated against the price of peak power in evaluating the cost effectiveness of an energy performance standard. This will have the effect of significantly tightening the level of the energy performance standard for those appliances that draw a substantial fraction of their power during periods of peak demand for electricity.

This project is designed to evaluate these two issues. Many tools are available to project the growth of average electrical demand in a utility service area. However, the analysis of the determinants of peak power is in relatively early stages of development. As a result, this project is seen as a multi-year effort and its primary goal is to advance the state of the art in the understanding of the factors influencing the growth of peak electrical demand. In the near term, the results will emphasize the qualitative and quantitative assessment effects of the residential energy standards (building and appliances) on peak power and the effects of the peak power impacts on these standards. In the long term, the project output should be particularly useful in two additional areas: (1) assessing the interactions among a wide range of federal energy policies and growth in demand for peak power and (2) utility load management planning to achieve a reduction in the growth in demand for peak electrical power.

UNIQUE ASPECTS OF THE STUDY

Utility planning for installation of new capacity requires load forecasting with particular emphasis on annual peak demand. Utility operations require similar forecasts of daily load curves. Existing methods accomplish these forecasts without an understanding of the instantaneous demand at the end use level. This reduces the reliability of the demand forecasts as well as severely limiting their utility in assessing impacts of energy performance standards on electric utilities and users of electricity.

This project investigates the shape of the load curve by starting at specific end uses and building upwards from the household demand, to system load. This is the opposite approach to current analyses, which colllect data about some aggregate load and seek correlation with averaged data (e.g., saturation of air-conditioners).

Analysis is directed toward clarification of coincidence of use among different appliances in the same household in addition to the more traditional coincidence of use for the same appliance among a population of households (diversity). This approach, expanded to treat industrial and commercial end uses, can explain the difference in time between the system peak and the residential air-conditioning peak in certain summer peaking utilities.

The greater level of detail achieved by considering individual end uses should result in a better understanding of causes of variability in weather and time-dependent demand. For example, present forecasting methods work well for predicting the average dependence of load on temperature, while the proposed method should reduce the range of error of such forecasts.

DESCRIPTION OF RESEARCH TASKS

Task 1: Collection of Existing Data

Much data is currently available bearing on time and weather demand, although only a small subset deals with demand at the end use level required for this analysis. Accessible data include:

- LBL data bases obtained from load surveys of residential end uses (including lighting);

- California Energy Commission forecasts and background information;

- Dynamics of total energy systems (Ref. 1).

- Office of Technology Assessment Solar Study (Ref. 2);

- Effects of weather variability on load (Ref. 3);

- Utility load curves, including:

  --Connecticut peak-load pricing experiment data and related analysis (Refs. 4 and 5).

  --Detroit Edison Company Summer 1975 air conditioning study (Ref. 6);

  --New York State Department of Public Service (Ref. 7); and

- U.S. Washington Center for Metropolitan Studies aggregate data on residential energy consumption for 1973 and 1975.

Task 2: Development of Peak Power Simulation Model

A preliminary methodology for analyzing aggregate demand as a function of constituent end use demands has been established. Inputs for each end use include: (1) capacity (or maximum load) of appliance; and (2) coefficient of use for each consumer class as a function of time of day, temperature and policy.

Calculations performed by the model include successive aggregation of the input data and derivation of diversities and average demands where appropriate. The general form of the calculation of demand by the j^{th} household for a time period (e.g., one hour) is:

$$D_{HH,h,T}^{(j,k)} = \sum_i COU_{k,i}(h,T,p) \cdot (SA_i) \cdot UEC_i(m)$$

where:

$UEC_i(m)$ is the hourly energy consumption of appliance i of type m (brand x);

SA_i is the "saturation" (= 1 if household has appliance i; = ∅ if not);

$COU_{k,i}$ (h,T,p) is the coefficient of use appliance i at hour h for consumer class k given condition of policy (or price) p and temperature (or season)T.

Appropriate summations give the daily demand of the household, the demand of all households of a given consumer class, and the total demand within a utility service area. Further calculations include coincidence of use of different appliances in a single household as well as coincidence of use for the same appliance among different households, and the diversified demand for the complete set of households in a specific utility service area.

Output from the model calculation will include: (1) aggregated demand (several households) versus time of day, i.e., daily load curve; (2) peak demand as a function of constituent end uses; (3) daily energy consumption per end use per household; (4) "diversity" of use for the same appliance in all households; and (5) "diversity" of use of different appliances in the same households. The model will be run first for a case in which no energy standards are assumed, based on the projection developed in other parts of the Appliance Energy Performance Standards (AEPS) program using the Oak Ridge National Laboratory (ORNL) Residential Demand Model. A second set of runs will analyze cases in which different energy standards are implemented by the government. The difference between the first and second sets of runs will provide a quantitative estimate of the effect of alternative standards on the peak loads of electric utilities.

Task 3: Application of Results to the Setting of the Levels of the Energy Performance Standards

The results of the model calculations will provide a basis for estimating the following parameters:

- fraction of peak power used by different residential appliances (including heating and cooling equipment);

- the sensitivity of peak power requirements of residential appliances to weather, conservation in the building shell, and appliance size and performance characteristics;

- the cost of the peak power requirements of the different appliances in different environments and locations; and

- the amount of oil and gas that is consumed by appliances as a result of their use of peak electrical power.

These data will be used directly to refine and improve the evaluation procedure for establishing the levels of the standards (see article in this volume on the appliance energy performance standards). Specifically, the life-cycle costing will take into account the cost or value of electricity used by different appliances, thus increasing the stringency of the standards for the appliances that draw a large fraction of peak power.

Task 4: Extension of Analysis to Other Key Policy Areas

This methodology will make possible an in-depth analysis of various load management strategies as they affect daily energy consumption and peak demand. The existence of different consumer classes as a function of daily activity patterns and demographic variables allows explicit treatment of changes in energy demand as a function of social or behavioral change. As more data on responses to different pricing schemes becomes available, these elasticities can also be added.

Some strategies of interest that may be examined with this model are:

- Direct load control by the utility. Experiments are already under way in some service areas where radio control of certain devices (air conditioners, water heaters) is initiated at high demand levels. This may involve complete interruption, or cycling of service to particular end uses when a certain demand level is exceeded (Ref. 6).

- Rate incentives to consumer. This voluntary measure provides economic incentives to utility customers to shift part of their demand to cheaper, off-peak times and has been shown to have significant effects in residential daily load curves.

- Conservation measures. As noted, the primary focus of the F.Y. 1980 effort has been the analysis of the effects of energy performance standards on peak loads. Additional research could analyze the effects of other energy conservation policies on peak loads: e.g., tax incentives, government financing strategies, involvement of utilities in billing for energy consuming consumer durables.

- Dispersed energy storage. Intuition leads to the expectation that dispersed storage will smooth load profiles; a quantitative estimate of those effects will be very valuable and can contribute to a clearer understanding of the economic trade-offs involved between investments in storage systems and in added generating capacity.

- Solar space heat/cooling. A significant penetration of solar systems into the market for home heating and cooling can have major effects on the shape of energy demand due to the possible weather-driven correlation of behavior of all such systems in a service area. This model provides a useful tool for evaluating the impacts of such a transition.

Finally, this model may be used for an estimation of peak demand under a wide range of conditions, but even more important than the estimation of that single measure is the attendant understanding of the components most responsible for growth in peak demand and of possible strategies for mitigating that growth.

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